



Proceedings of CIB Facilities Management Conference

Using Facilities in an open World creating Value for all Stakeholders

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Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):
Jensen, P. A. (Ed.) (2014). *Proceedings of CIB Facilities Management Conference: Using Facilities in an open World creating Value for all Stakeholders*. Polyteknisk Boghandel og Forlag.

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PROCEEDINGS OF CIB FACILITIES MANAGEMENT CONFERENCE USING FACILITIES IN AN OPEN WORLD CREATING VALUE FOR ALL STAKEHOLDERS

**JOINT CIB W070, W111 & W118 CONFERENCE
TECHNICAL UNIVERSITY OF DENMARK
COPENHAGEN, 21 - 23 MAY 2014**

PER ANKER JENSEN (EDITOR)



**International Council
for Research and Innovation
in Building and Construction**


Polyteknisk
Forlag

FOREWORD

The CIB Facilities Management conference is arranged biannually by CIB Working Commission W070. The conference in 2014 is organised in collaboration with W111 Usability and W118 Clients and Users and the local host Centre for Facilities Management at the Technical University of Denmark.

An organising committee with the coordinators of CIB W070, W111 and W118 has under my chairmanship as local host planned and organised the conference. The scientific committee has consisted of well qualified senior researchers from around the world. The members of both committees are listed on the next page followed by introductions by the coordinators of each of the three working commissions.

In this joint conference amongst working commissions we focus on the importance of increased openness in the world and how FM can create value for all stakeholders. With the first announcement we invited for inputs on the more specific conference themes. Based on those inputs a number of themes were defined for the call for paper. A total of 66 abstracts were received. Abstracts and papers have been through a rigorous double blind review process resulting in the acceptance of 38 papers included in this publication.

The papers are grouped in 10 themes and presented as part of research tracks during the conference. They are included in chapter 1-10 in these proceedings. Four papers were included in two practice tracks together with presentations by invited practitioners. These papers are included in chapter 11 and 12. An index of keywords from all papers is included at the end of the publication.

I thank all authors and the scientific and organizing committee for their great work. I wish the conference participants and readers of the papers in these proceedings an enjoyable experience and a lot of inspirations for further research and the application into education and practice.

May the CIB Facilities Management Conference in Copenhagen May 21-23 2014 become a fruitful source to build on!



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Proceedings of CIB Facilities Management Conference 2014

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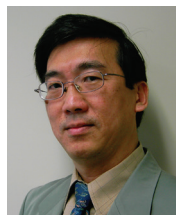
INTRODUCTION FROM CIB W070

CIB Commission W070 Facilities Management and Maintenance was established in 1979 to coordinate and support the development of the Facilities Management and Building Maintenance disciplines through the exchange of knowledge and information between academia, industry and practitioners. In particular the Commission aims:

- to foster a deeper understanding of how our built environment influences human behaviour, health and organizational productivity
- to promote the strategic and operational value of facilities management and asset maintenance in meeting emerging business challenges
- to forge closer links and collaboration between the financial, technical, sociological and operational aspects of facilities management and asset maintenance through an integrated resource management approach
- to disseminate the findings of research work on facilities management and asset management to a wider audience
- to provide a forum for the exchange of know-how and best practice in education, research and industry that addresses physical workplace and functional workspace demands
- to communicate the work of CIB W070 by publication of its symposium proceedings.

Over the years the Commission has hosted 16 international conferences and estimated to have published over 650 papers in various aspects of facilities management and asset maintenance. It is obvious that, over its 35 years of history, the scope and content of CIB W070 has moved from its original focus of maintenance of public sector housing to embrace the growing significance and recognition of facilities management as an inclusive field covering the provision and management of building assets, workplace facilities within building assets, and facilities support services. The topics covered within the current conference is a clear reflection of that, covering some of the key issues affecting today's built environment, from sustainability and climate change to workplace management and building performance. The collaboration with other related working commissions (W092, W111, W118) and task group (TG72) in this and previous conference in Cape Town in 2012, provides a wider platform for exchange of ideas and interactions within the CIB family.

As joint coordinators of CIB W070 we hope you find the conference presentations both challenging and stimulating and that you leave the conference more knowledgeable about the role that Facilities Management and Building Maintenance can play in shaping our urban environment. We also look forward to renewing old friendships and forging new ones as we seek to grow as an international community.



Danny Then & Keith Jones
Joint coordinators of CIB W070

INTRODUCTION FROM CIB W111

The CIB W111 Usability Group was founded as a task group (TG51) in 2001 to investigate the application of the international standard on Usability (ISO 9421) to Facilities Management and the built environment. Since then the work on usability has been developed through several stages from the first exploratory case studies, to development of theory, methods and tools, the application of new knowledge into a number of case studies and the implementation of the concept of usability in several organizations and companies. The usability network has grown from a small interest group, to an international network that contributes to further development of the field.

This year's joint conference together with the W070 Facilities Management and W118 Client and Users really underlines the importance of the usability concept and the strong relation to the other work groups. In the end it is the usability and the use(r) value of our common environments that really counts. In these proceedings you will find two chapters on usability. Chapter 7, Usability and User Experiences, with 4 papers on user experiences from two projects; One on neighborhood and the other on relocation. The two other papers contribute to further development of usability related to briefing and use-centric method. In chapter 9, Usability and Learning Environments, you will find some interesting papers on academic co-working space, interdisciplinary learning communities, space management in higher education, and the first usability paper discussing opportunities in physical and virtual learning environments. The 8 papers on usability really contribute to the main topic of this conference; Using Facilities in an Open World - Creating Value for all Stakeholders. I hope the reading will inspire you take the usability perspective into your own work and to further development of the field.



Geir K Hansen
Coordinator of CIB W111

INTRODUCTION FROM CIB W118

Buildings are not just about building. Rather, it is a two-sided coin of both production of buildings and consumption of buildings. The joint conference “Using Facilities in an Open World – Creating Value for all Stakeholders” offers a unique opportunity to focus on the often overlooked side of the coin related to the consumption of buildings through the perspective of clients, users and facility managers.

Looking at the lifecycle of buildings, two value chains related to the supply of buildings and the consumption of buildings come into focus. One value chain is occupied with the supply of buildings. In an overly simplified version it consists of design and construction involving the usual actors of the building process like architects, engineers, contractors, suppliers etc. The other value chain is related to the demand side of building. We may want to think wide and broadly on the demand side to include not only clients and users, but also investors, owners and facility managers (including do-it-yourself). Further, the concept of users may be extended to include not only the immediate users, but also other relevant stakeholders like neighbours etc.

The CIB Working Commission W118 on Clients and Users in Construction was established in October 2010 as a successor to the previous CIB Priority Theme on Clients and Users. Clients and users play a significant role in shaping construction and real estate through various social, technological, economic, environmental and political drivers. Getting a better grasp of the aspirations, needs and behaviour of users and clients may offer an important new road for the industry to deliver more value for money. The aims of W118 are:

- to bring together the experience and expertise of researchers and practitioners,
- to develop, share and disseminate appropriate research theories and methodologies for successful client management of procurement and innovation, and
- to encourage and facilitate new collaborative and multi-disciplinary research both within and outside of CIB.

The Working Commission CIB W118 will 1) investigate what constitutes clients and users in building, 2) identify appropriate procurement and management strategies, 2) classify methods for engaging users in decision making processes, and 4) develop appropriate related guidance material for clients and users.



Kim Haugbølle & David Boyd
Joint coordinators of CIB W118

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CHAPTER 1

FM PERFORMANCE AND INDUSTRY MATURITY

1.1

A framework for Key Performance Indicators for a Holistic Facility Performance Assessment

S. Lavy, J.A. Garcia and M.K. Dixit

1.2

Theoretical Underpinnings of the Feeder Factors Integration Framework

Maulidi A. Banyani and Danny S S. Then

1.3

Making-do – Illusion of Effective Service Processes

Tuuli Jylhä, Heidi Rasila and Auli Karjalainen

1.1

A FRAMEWORK FOR KEY PERFORMANCE INDICATORS FOR A HOLISTIC FACILITY PERFORMANCE ASSESSMENT

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ABSTRACT

Purpose: The primary purpose of this paper is to identify core Key Performance Indicators (KPIs) that are critical to assessing a facility's physical, functional, and financial performance. This paper also lists and discusses key variables that affect the identified KPIs.

State of the Art: The KPI approach to performance assessment ascertains comprehensiveness and provides users the flexibility to select a metric of their choice. Although numerous studies have established a list of KPIs, the list includes performance measures that are redundant. Literature has specifically indicated a need to provide a concise list of core indicators that are quantifiable based on readily available information.

Approach: A qualitative method, which uses a combination of a literature-based and industry opinion-based approach, is adopted to derive mathematical expressions to quantify core KPIs. A limitation of using this research method is that there was only one facility management firm involved in providing the industry perspectives; however, this firm has experienced personnel, dealing with facility asset management issues all over the world for many years.

Results: Four quantitative KPIs are proposed to evaluate a facility's maintenance, replacement program, physical condition, and functional suitability. Additionally, a tool is designed to qualitatively assess indoor and outdoor atmospheres.

Practical Implications: The core KPIs are significant for performance assessment, as they are quantifiable based on the availability of industry data. This may also be used as a managerial approach to improve a facility's performance so that the facility works toward achieving organizational goals.

Originality/Value: The study provides a list of core indicators that can be quantified using readily available information in the industry.

Keywords: Facility Management, Performance, KPIs, Assessment.

1 INTRODUCTION

As performance assessment involves a review of past and present performance of a built facility and a comparative evaluation of its performance within and across an organization, its role in establishing strategies and making future decisions is significant. In addition, the results of performance assessment can evaluate the facility for its contribution to accomplishing organizational goals (Amaratunga et al., 2000; Douglas, 1996). To keep the process of facilities' performance improvement continuous and consistent, regular feedback from the performance assessment team is important (Cohen et al., 2001).

A KPI approach provides the freedom to select the performance metrics of choice based upon the scope of a study or user needs. The process of performance assessment using KPIs starts with the selection of measurable and quantifiable indicators based upon the study's scope, type of users, the nature of the organization, performance assessment focus, and current industry trends and demands (Amaratunga et al., 2000).

Although an extensive list of performance metrics exists, it includes indicators that are redundant and may not be measurable or applicable (Shohet, 2006; Lavy, et al., 2010). For a focused and holistic performance evaluation, it is important to identify and select core KPIs that can be both quantified and used to assess more than one aspects of a facility's performance in a detailed manner (Amaratunga et al., 2000; Douglas, 1996; Epstein and Wisner, 2001). Among the main aspects measured are the efficiencies of a facility's maintenance and replacement performance that eventually affect its condition. Reduction in maintenance expenditure while maintaining a healthy, safe, and comfortable indoor atmosphere is almost always emphasized (Horner et al., 1997; Shohet and Lavy, 2004; OLA, 2000). It is also important to evaluate how the facility under study is carrying out its scheduled replacements (APPA et al., 2003). The Facility Condition Index (FCI), which is an indicator of a facility's condition, is a ratio of its deferred maintenance and the total current replacement value (Briselden and Cain, 2001; Teicholz and Edgar, 2001). Another important assessment is to know whether the facility is supporting the function it is designed for. Conventionally, a facility's functional performance is measured in terms of space management and utilization (Douglas, 1996; Douglas, 1993/94). The process of functional evaluation helps in organizing the current portfolio of spaces by identifying under-utilized and over-utilized spaces. Other performance aspects, such as indoor and outdoor environmental quality, can also significantly influence occupants' perception, productivity, absenteeism, and turn-over rate, which may have serious financial implications (Mozaffarian, 2008; Prakash, 2005; Fowler et al., 2005).

The literature (Hinks and McNay, 2005; Ho et al., 2000; Slater et al., 1997; Amaratunga et al., 2000; Douglas, 1996) indicates that there is a strong need to develop a concise set of core indicators that are relevant, quantifiable, and measurable. In this paper, core KPIs are identified and mathematical expressions for their calculation are proposed. In addition, variables influencing the KPIs are also discussed and defined.

2 RESEARCH METHODS

As suggested by the literature, this study applies a research method that includes deriving a list of performance indicators from a rigorous literature review, categorizing them, and identifying indicators that are quantifiable and can express more than one aspect of a facility's per-

formance (Hinks and Macnay, 1999; Ho et al., 2000; Slater et al., 1997). This paper builds upon an earlier study (Lavy et al., 2010), in which a wide range of KPIs were collected by surveying the literature. In addition, collected KPIs were categorized under four main categories: (1) physical; (2) financial; (3) functional; and (4) survey-based. The main criterion for selecting the core KPIs was that they should be measurable and quantifiable based on information readily available in the industry. In addition, key variables affecting the core KPIs were identified and discussed using literature survey and industry inputs. Industry inputs were useful, particularly in identifying variables which can be quantified using easily available data. It was assumed that a facility's environmental performance was better assessed by the LEED® Green Building Operations and Maintenance Reference Guide, and this guide was selected as a reference for the refinement and development of the Indoor/Outdoor Environmental Quality (IOEQ) indicator. Various user perception aspects were also gathered, discussed, and categorized. Finally, using the industry and literature inputs, mathematical equations to quantify the core KPIs were proposed and explained.

Major industry input was gathered from a leading professional facility asset management firm serving worldwide. The firm is engaged in providing services such as key facilities performance metrics consulting, capital planning, facility condition and environmental assessments, real property inventory management, facility use studies, investment strategies, and computer aided facility management systems consulting and information systems development.

3 LITERATURE REVIEW

3.1 Performance Assessment and KPIs

A facility's performance evaluation is important for understanding its role in supporting organizational functions and goals. In addition, the results of performance assessment guide decisions such as facility expansion, real estate acquisition, and facility renovation and retrofitting (Amaratunga et al., 2000; Douglas, 1996). Among major performance evaluation methods is the KPI approach in which a set of performance metrics are measured. The performance metrics correspond to facility performance objectives (Ho et al., 2000; Douglas, 1996). Varcoe (1996) suggested that performance objectives, which relate to organizational goals, can be transformed into performance metrics. Using such metrics assures measurement of aspects that are primary to the organization. Moreover, this process of developing performance metrics enables identification of additional indicators that could emerge as a result of a change in the organizational strategies as well as objectives. One major advantage of using a KPI approach is that it is relatively comprehensive and it provides the opportunity to select a performance metric of choice (Lavy et al., 2010). To provide a wider applicability and choice of performance metrics, Douglas (1996) and Ho et al. (2000) suggested arranging them in categories such as financial and nonfinancial KPIs. Another aspect of KPIs that had been pointed out by studies such as Slater et al. (1997) and Ho et al. (2000) is a need to establish a concise list of performance metrics. The available sets of KPIs are long and include metrics that are redundant and not quantifiable. In addition, past performance assessments centered solely on financial metrics; now, they must also address non-financial aspects such as business, organization goals, job satisfaction, indoor and outdoor environmental issues, and other non-financial qualitative aspects (Amaratunga et al., 2000; Douglas, 1996; Epstein and Wisner, 2001).

3.2 Indicators for Facility Performance Assessment

The literature has expressed a need to propose a concise set of performance metrics that can measure a facility's performance based on the readily available information. The following KPIs have been discussed widely in the literature:

Maintenance Efficiency

One important aspect of a facility's performance is measuring how effectively the facility management personnel is performing its maintenance. The annual maintenance expenditure consists of preventive and corrective maintenance components. Preventive maintenance is scheduled to avoid a sudden break-down of a system, whereas corrective is performed when a system has already broken down. A conventional facility management practice is to optimize maintenance expenditure by simultaneously keeping a facility safe, comfortable and profitable (Horner et al., 1997; Shohet and Lavy, 2004; OLA, 2000). In spite of numerous maintenance evaluation metrics, previous research has suggested that proven performance metrics for maintenance assessment are still missing and past studies have failed to provide a quantifiable and measurable maintenance performance indicator (Shohet, 2006; Chan et al., 2001). The evaluation of maintenance performance involves assessing the effectiveness and efficiency of preventive maintenance (OLA, 2000). Strategies for optimizing maintenance expenditure are affected by scheduled maintenance (preventive maintenance), which cannot be determined easily (Horner et al., 1997). According to Pati et al. (2009) and Park and Augenbroe (2003), the Maintenance Efficiency Indicator (MEI) quantifies the efficiency with which a facility utilizes its maintenance budget. MEI is an effective indicator of maintenance, and the indicator can significantly affect strategic decision-making (Pati et al., 2009).

Replacement Efficiency

In addition to maintenance efficiency, it is also important to evaluate a facility's replacement program, which involves replacing facilities and systems that are damaged or approaching their end-of-life (OLA, 2000). One major issue with replacement activities is that these are not the same each year, making their estimation a difficult task. According to studies (State Council of Higher Education, 2001; Fagan and Kirkwood, 1997), capital renewal can be used to evaluate a facility's replacement performance. Capital renewal index, which is a ratio of the annual capital renewal to the current replacement value, can measure the replacement performance of a facility (APPA et al., 2003).

Condition Index

The condition of a facility is evaluated by quantifying a Facility Condition Index (FCI), which is the ratio of maintenance deficiency to the Current Replacement Value (CRV) (Briselden and Cain, 2001; Dept. of Interior, 2008; Teicholz and Edgar, 2001). The deficiency of maintenance represents current maintenance and repair work pending (Briselden and Cain, 2001; Dept. of Interior, 2008). The CRV is the monetary requirement to restore a facility or a system to its "good as new" condition without modification (Dept. of Interior, 2008). The condition of a building is perceived by its users through its appearance and the quality of indoor atmosphere, which cannot be quantified. The FCI provides a way to quantify condition of a facility in monetary terms (Briselden and Cain, 2001). The condition of a facility can also be expressed as a percentage using an index called Condition Index (CI), which is calculated using FCI (Watson, 2009; Teicholz and Edgar, 2001). The values of CI can be calculated at a system, facility, or campus level (Teicholz and Edgar, 2001; Watson, 2009). The calculated values of CIs at a system level then can be weighted to quantify a facility level CI. It should be noted that only systems or components contributing to a facility's integrity and

functionality should be included in the calculation of CI to avoid influence of other non-contributory components (Dept. of Interior, 2008).

Functional Space Index

Other than monetary indices such as MEI and CI, the functional suitability of a facility should also be measured. The amount, quality and shape of the spaces provided by a facility govern its functional performance (Douglas, 1996; Loosemore and Hsin, 2001). The amount of space and its quality affect the occupants' productivity and eventually, organizational goals (Hinnum, 1999; Cole and Brown, 2009). According to Hinnum (1999), space adequacy in schools is an important factor determining the performance of students. Douglas (1993/94) suggested identifying spaces that are under and over-utilized. He also suggested using space utility as a metric to assess the spatial efficiency of a facility. The sufficiency of space can be evaluated by comparing the existing spaces to relevant space standards for various facility types (Hammond et al., 2005). According to Loosemore and Hsin (2001), spaces should be assessed in terms of their contribution to the core objectives of the organization.

Indoor/Outdoor Environmental Quality (IOEQ)

As building occupants are exposed to a relatively higher level of pollutants for an extended period of time, Indoor Environmental Quality (IEQ) has become a major concern for building design, construction, and management professionals (USEPA, 2009). An adverse quality of indoor atmosphere seriously hampers employees' performance and productivity, affecting their turnover rate, absenteeism, and mental satisfaction (Fowler et al., 2005). Adverse IEQ in most cases could cause financial burdens for an organization, through paid leaves and compensation (Prakash, 2005). In addition to increased productivity and reduced financial burden, an enhanced IEQ boosts employees' confidence in an organization's ability to provide a safe, comfortable, and healthy workplace (Mozaffarian, 2008, Prakash, 2005; Fowler et al., 2005). Most currently used building assessment systems around the globe include the assessment of IEQ (Fowler et al., 2005; Malmqvist, 2008). Among them is the LEED rating system, which demonstrates popularity and a wider acceptance among building design and construction professionals (Malmqvist, 2008). Bray and McCurry (2006) argued that not only the indoor but also the outdoor environmental quality should be evaluated by accepted building assessment systems.

Absenteeism and User Perception

Fleming (2004) argued that facility managers are more interested in the technical and financial performance of their facilities rather than the perceptions of their occupants (Fleming, 2004). Nevertheless, an adverse workplace quality could affect the perception of a facility's occupants, which may cause absenteeism and high employee turn-over rate (Fowler et al., 2005). It was found that in educational facilities, a conducive and healthy indoor atmosphere may improve students' learning (Olson and Kellum, 2003; Brooks-Pilling and Wright, 2005). Increased absenteeism in a facility may be the result of a poor indoor environment (Olson and Kellum, 2003; Brooks-Pilling and Wright, 2005). Studies conducted by institutions such as the Thomas Jefferson Center for Educational Design at the University of Virginia, and the U.S. District Court, Northern District of California (by Biegel, 2000) indicated that students' performance may be governed by the quality of indoor atmosphere. In the case of an organization, it is important to ensure that employees are satisfied with the workplace atmosphere. These employees play an important role in organizational success, and their satisfaction level and confidence in the organization could provide significant business benefits (Tucker and Smith, 2008).

4 FINDINGS

4.1 Maintenance Performance: Maintenance Efficiency Indicator (MEI)

The Facility Condition Index (FCI) demonstrates a facility's condition, which is a combined effect of its maintenance and replacement performance. However, FCI does not provide the assessment of maintenance and replacement programs individually. The main objective of a Maintenance Efficiency Indicator (MEI) is to assess how efficiently the maintenance is being done by a facility. It is assumed that the total maintenance expenditure is the sum of preventive and corrective maintenance. The following section discusses key variables that affect the MEI.

Spending on Deferred Maintenance (SDM)

The SDM provides an assessment of actual maintenance being done. It is calculated as the ratio of actual to expected deferred maintenance. It is important to know what fraction of expected maintenance is being performed by a facility. The SDM is calculated as:

$$SDM = \frac{DM(Actual)}{DM(Expected)} \times 100$$

Where, the term "DM" represents deferred maintenance.

Maintenance Efficiency Indicator (MEI)

The maintenance performance of a facility then can be quantified using the calculated values of SDM and Condition Index (CI). For a given period, the maintenance Efficiency Indicator (MEI) is calculated as the ratio of SDM to CI of a facility. MEI can be derived as:

$$MEI = \frac{SDM}{CI} \times 100$$

The MEI can be calculated at a given point in time and also for a specific period of study.

Corrective to preventive maintenance ratio (CPR)

This ratio is significant in identifying the fraction of corrective and preventive maintenance expenditure in total maintenance expenditure. It is calculated as the ratio of corrective to preventive maintenance. A CPR value of greater than one indicates that the facility's systems are breaking down too often as a result of insufficient preventive maintenance. Thus, this ratio can be termed as:

$$CPR = \frac{M_c}{M_p}$$

where M_c and M_p are corrective and preventative maintenance, respectively. It is more meaningful if CPR is calculated for a longer period of time (e.g., several years) to discover the pattern of maintenance expenditure. Such a pattern could help derive strategies to optimize maintenance expenditure.

4.2 Replacement Efficiency Indicator (REI)

In addition to MEI, it is important to analyze the contribution of a facility's replacement program in its CI. The replacement efficiency of a facility can be quantified using data of the total capital renewal done and the total systems expired in a given year. Two aspects of replacement are important: the total replacement expenditure and the schedule of replacement. It is assumed that the service life of a facility's systems is shorter than the facility itself. The total value of the capital renewal at the end of year is considered in the calculation. The REI can be calculated as the ratio of total capital renewal to the total cost of expired systems at the end of the year. REI is given by:

$$REI = \frac{\sum Cap.Re n.(\$)}{\sum Exp.(\$)}$$

An REI equal to one indicates that the facility is replacing its systems as they are expiring. An REI less than one could mean the facility is lagging behind in replacing expired systems. Like MEI, this ratio can also be expressed in % by multiplying it by 100. As it is a better strategy to replace a system as soon as it expires, an REI compares actual replacement to the expected replacement. REI provides an individual assessment of a facility's replacement program by tracking not only replacement expenditure but also replacement schedule. The combined effect of REI and MEI can be expressed by the calculated value of FCI, which takes into account total deficiencies and CRV.

4.3 Functional Space Index (FSI)

As discussed in the literature review section, the functional appropriateness of a facility can be measured by evaluating its spaces in terms of their size, shape, and quality. The Functional Space Index (FSI) is a unit-less ratio that is calculated as the ratio of actual to required gross square footage for different types of spaces. The FSI can be calculated at individual space, building, and campus levels. The calculation of FSI at a detailed level (e.g. individual space level) provides a relatively accurate picture of what is causing the functional deficiency as well as the most pragmatic solution. The required space area can be sourced from applicable space standards. In some cases, a threshold value of required space area is set at a level below which the space would be functionally unfit for supporting organizational functions (e.g. learning and teaching).

The key variables required to quantify FSI include total required space area, total actual space area, number of spaces, space types, and cost per square foot of new construction of the space (obtained from sources such as cost data catalogs). The data for these variables need to be collected for each space type, as spaces may have different spatial and functional requirements. The space area information does not include common areas such as lobbies, hallways, and service areas, as the area considered is not the gross floor area. Space level FSI can be calculated as:

$$FSI = \left(\frac{\text{Total Space Area (by space type)}_{\text{Actual}}}{\text{Total Space Area (by space type)}_{\text{Required}}} \right)$$

Another calculation of FSI takes an entire building into account rather than one space. Calculating FSI at a building level allows the user to diagnose and address configuration issues in a school. These issues can lead to a deficient FSI that can be fixed by reconfiguring existing space rather than constructing new space. Building level FSI can be calculated as:

$$\text{Building FSI} = \sum_{\text{Building}} \left(\frac{\text{Total Space Area (by space type)}_{\text{Actual}}}{\text{Total Space Area (by space type)}_{\text{Required}}} \right) \times \# \text{ of spaces (by space type)}$$

The value of FSI greater than or equal to one would indicate that the space provided is functionally adequate. However, if the value of FSI is more than one, the space may be under-utilized for the function it is supporting. A value of FSI less than one shows that the space is functionally deficient, and the output will be the total area required multiplied by the cost per square foot of new construction. This value would provide the cost to correct the functional deficiency of the space.

4.4 Indoor/Outdoor Environmental Quality (IOEQ) Indicator

An environmental metric evaluating the quality of not only indoor but also outdoor environment is instrumental. The IOEQ indicator proposed to assess a facility's environmental performance is calculated based on the measurements, metrics, and benchmarking standards established in the LEED® Green Building Operations and Maintenance Reference Guide (USGBC, 2009). For the purposes of data collection and analysis, a spreadsheet calculator is proposed based on the environmental metrics from the LEED® Green Building Operations and Maintenance Reference Guide. The calculator utilizes the dynamic LEED credit templates for submitting project documentation available only to the team members of a registered LEED® project. The calculator is organized by LEED credit and by category. For instance, as shown in Figure 1, formulas for the calculation for Sustainable Sites, Credit 5 – Site Development: Protect or Restore Open Habitat are embedded in the spreadsheet calculator.

Figure 1: Calculation for Sustainable Sites Credit 5.0

5.0.A	DOES NATIVE OR ADAPTED VEGETATION COVER:	
5.0.A.1	25% OR MORE OF THE SITE AREA (EXCLUDING BUILDING FOOTPRINT) ?	NO
	BUILDING FOOTPRINT :	100000 SF
	TOTAL SITE AREA :	150000 SF
	TOTAL NET ON-SITE AREA :	50000 SF
	ON-SITE AREA COVERED IN NATIVE OR ADAPTED VEGETATION :	0 SF
	% OF SITE AREA XERISCAPED :	0.0%
5.0.B	IF THERE EXISTS CONTRACTED OFF-SITE VEGETATED AREA, DOES IT COVER:	
5.0.B.1	25% OR MORE OF THE SITE AREA (EXCLUDING BUILDING FOOTPRINT) ?	YES
	BUILDING FOOTPRINT :	100000 SF
	TOTAL SITE AREA :	150000 SF
	TOTAL NET ON-SITE AREA :	50000 SF
	TOTAL OFF-SITE AREA COVERED IN NATIVE OR ADAPTED VEGETATION:	25000 SF
	TOTAL ON-SITE AREA COVERED IN NATIVE OR ADAPTED VEGETATION:	0 SF
	% OF ON- AND OFF-SITE AREA XERISCAPED :	25.0%

The IOEQ spreadsheet determines the total number of points achieved for each environmental category. As the IOEQ spreadsheet calculator utilizes 77 out of 110 maximum possible points, the corresponding certification ratings are proportionately adjusted as follows:

Certified	28 Points
Silver	35 Points
Gold	42 Points
Platinum	56 Points

Although these certification ratings do not affect the calculation of any of the proposed indicators such as CI, MEI, REI, and FI, they certainly provide a qualitative assessment of the indoor and outdoor environment a facility provides to its occupants.

4.5 User Perception

The perception of a facility's occupants is evaluated qualitatively. Surveys are among the most commonly used data collection tools to investigate user perception, with the two key approaches being subjective and objective surveys. In an objective survey, an observer collects data by observing directly the facilities and their occupants. In the subjective approach,

however, data is collected from occupants, using a questionnaire. Preiser (1995) suggested carrying out post occupancy evaluation (POE) at the three levels of health, safety and security; functionality and efficiency; and psychological, aesthetical and socio-cultural aspects (See Table 1).

Table 1: Three categories of post occupancy evaluation (based on Preiser, 1995)

Study	Health, safety and security	Functionality and efficiency	Aesthetic and socio-cultural
CEFPI, 2007	Maintenance and serviceability	Learning and environment	Sustainability
Hygge and Lofberg, 1999	Light, noise, temperature, ventilation	Space, windows	View out, privacy, general environment
Brooks and Viccars, 2006	Internal environment, citizen satisfaction	Use, access, space, performance, engineering, construction	Urban and social integration, character and innovation
Brooks and Viccars, 2006	Internal environment	Use, access, space, performance, engineering, construction, form and material	Urban and social integration, character and innovation, form and material
Brooks and Viccars, 2006	Personal control, comfort, noise, overall comfort, health, lighting	Overall building, quickness of response, response to problems, productivity at work, your desk or work area, travel to work	Travel to work
Zimring et al., 2008	Quality of work life, personal productivity, psychological and social well being	Operating/maintenance cost, cost of building related litigation, resale value of property, rentability of space etc., process innovation, work process efficiency, product quality, time to market	Public image and reputation, customer satisfaction, community relationships
Fleming, 2005	Availability of natural light, security of personal possessions, temperature changes, effect of solar glare, ability to see out, informal relaxed atmosphere, general background noise, quiet rooms, variations in noise level, mobile phone noise, indoor relaxation areas, internal visibility, circulation space noise, occupation density, privacy, hub noise, personal control of temperature	Access to printers Quality of artificial light Amount of desk space Window proximity Formal meeting facilities Quiet rooms Support facilities Intranet information Workspace ownership Personal storage Outdoor areas Catering Location in building Entrance impact	Casual meeting areas Feeling of equality Internal visibility Internal aesthetics Access to colleagues
Tucker and Smith, 2007	Personal control, privacy, personalization	Windows and lighting	Interior planting, color windows and lighting
		Space, serviceability, operational cost, operational management, life cycle cost	
Saidi, 2007	Accessibility, safety, internal views, housekeeping and cleanliness, physical comfort, surrounding environment	Signage, layout, waiting time and waiting rooms, treatment	Image of the hospital building, privacy and respect for patients, space requirements, support of family and friends

5 CONCLUSIONS

The assessment of a facility's performance is important not only to make future resource optimization decisions but also to improve the performance of its occupants, both of which could result in significant financial and business benefits. Using KPIs for such assessments provides an opportunity to select the performance metrics of interest. Literature has suggested deriving a concise list of quantifiable and core indicators from published studies. This paper focused on developing a concise but relevant list of five KPIs, which are quantifiable, and which can assist with assessing facility performance comprehensively. With an intent to include only those indicators that can measure more than one aspect of a facility's performance, we focused on indicators that measure the physical condition, functional suitability, and recurring activities such as maintenance and replacement of a facility. We propose CI which measures overall condition of a facility in financial terms and is dependent on maintenance and replacement strategies. To measure individual contribution of a facility's maintenance and replacement strategies, we propose two indicators, namely MEI and REI. It is important to note that all three indicators (CI, MEI, and REI) influence one another and a tool that can analyze their mutual impacts is currently lacking. In the literature, the assessment of space utilization has also been emphasized. Two qualitative KPIs are proposed to evaluate indoor and outdoor environmental quality and user perception. Both of these qualitative indicators can significantly affect an organization's business performance by affecting employees' productivity and turn-over rates. Our next phase of the study will include investigating the mutual relationships between the five KPIs, as proposed and developed in this paper.

REFERENCES

- Amaratunga, D., Baldry, D., and Sarshar, M. (2000), "Assessment of facilities management performance – what next?" *Facilities*, 18, 1/2, 66-75.
- APPA, FFC, HOLDER, IFMA, and NASFA (2003), Asset lifecycle model for total cost of ownership management, framework, glossary & definitions, retrieved on 25 February 2009 from http://www.ifma.org/tools/research/Asset_Lifecycle_Model.pdf.
- Biegel, S. (2000). The interface between attendance, academic achievement, and equal educational opportunity, Report no. 17, U.S. District Court, Northern District of California, San Francisco, 27 July, 2000.
- Bray, J., and McCurry, N. (2006), "Unintended consequences: how the use of LEED can inadvertently fail to benefit the environment", *Journal of Green Building*, 1, 4, 152-165.
- Briselden, D., and Cain, D. (2001), The facilities condition index: A useful tool for capital asset planning, Facility manager Magazine, APPA, Alexandria, Virginia, USA.
- Brooks-Pilling, T., and Wright, C.L. (2005), "Building schools that support learning," *Building Operating Management*, September, 2005.
- Chan, K.T., Lee, R.H.K., and Burnett, J. (2001), "Maintenance performance: a case study of hospitality engineering systems," *Facilities*, 19, 13/14, 494-503.
- Cohen, R., Standeven, M., Bordass, B., and Leaman, A. (2001), "Assessing building performance in use 1: the Probe process", *Building Research and Information*, 29, 2, 85-102.
- Cole, R.J., and Brown, Z. (2009), "Reconciling human and automated intelligence in the provision of occupant comfort," *Intelligent Building International*, 1, 1, 39-55.
- Council of Educational Facility Planners International (CEFPI) (2007), Post Occupancy Evaluation, Alberta Chapter, Spring 2007 Conference, Council of Educational Facility Planners International, Scottsdale, AZ, USA, retrieved from <http://media.cefpi.org/docs/PostOccupancyEvaluation07.pdf>.

- Department of Interior (2008), Policy on deferred maintenance, current replacement value and facility condition index in life-cycle cost management, retrieved on 16 August 2009 from <http://www.doi.gov/pam/PolicyDMCRV53008.pdf>.
- Douglas, J. (1993/4), "Developments in appraising the total performance of buildings", *Structural Survey*, 12, 6, 10-15.
- Douglas, J. (1996), "Building performance and its relevance to facilities management", *Facilities*, 14, 3/4, 23-32.
- Epstein, M.J., and Wisner, P.S. (2001), "Using a Balanced Scorecard to implement sustainability" *Environmental Quality Management*, 11, 2, 1-10.
- Fagan, M.M., and Kirkwood, D.M. (1997). Facility condition assessments: More than just making a list, in 34th Annual Conference and Technical Exhibition, American Society for Healthcare Engineering, San Antonio, Texas, 15 July 1997.
- Fleming, D. (2005), "The application of a behavioural approach to building evaluation," *Facilities*, 23, 9/10, 393-415.
- Fowler, K.M., Solana, A.E., and Spees, K. (2005), *Building Cost and Performance Metrics: Data Collection Protocol*, Pacific Northwest National Laboratory, Richland, Washington, USA.
- Hammond, D., Dempsey, J.J., Françoise, S., and Gerald, D. (2005), "Integrating a performance-based approach into practice: a case study", *Building Research and Information*, 33, 2, 128-141.
- Hinks, J., and MaCnay, P. (1999), "The creation of a management-by-variance tool for facilities management performance assessment", *Facilities*, 17, 1/2, 31-53.
- Hinum, M. (1999), "Strategies for Managing Educational Facilities Infrastructure," Track 3 of the UEF/PEB/CAE International Symposium, Baltimore, Maryland, USA.
- Ho, D.C.H., Chan, E.H.W., Wong, N.Y., and Chan, M. (2000), "Significant metrics for facilities management benchmarking in the Asia Pacific region", *Facilities*, 18, 13/14, 545-555.
- Horner, R.M.W, El-Haram, M.A., and Munns, A.K. (1997), "Building maintenance strategy: a new management approach," *Journal of Quality in Maintenance Engineering*, 3, 4, 273-280.
- Hygge, S., and Lofberg, H. A. (1999), Post occupancy evaluation of daylight in buildings. Report: IEA SHC TASK 21 / ECBCS ANNEX 29, Energy Conservation in Buildings and Community Systems Programme, International Energy Agency, December, 1999.
- Lavy, S., Garcia, J.A., and Dixit, M. (2010), "Establishment of KPIs for facility performance measurement: Review of literature," *Facilities*, 28, 9, 440-464.
- Loosemore, M., and Hsin, Y.Y. (2001), "Customer-focused benchmarking for facilities management", *Facilities*, 19, 13-14, 464-476.
- Malmqvist, T. (2008), "Environmental rating methods: selecting indoor environmental quality (IEQ) aspects and indicators," *Building Research & Information*, 36, 5, 466-485.
- Mozaffarian, R. (2008), "Life-cycle indoor air quality comparisons between LEED certified and non-LEED certified buildings," M.S. Thesis, University of Florida, Gainesville, USA.
- Office of the Legislative Auditor (OLA). (2000). "Preventive maintenance for local government buildings," Office of the Legislative Auditor, State of Minnesota, St. Paul, Minnesota, USA, 12 April 2000.
- Olson, S.L., and Kellum, S. (2003), The impact of sustainable buildings on educational achievements in K-12 schools, Leonardo Academy Inc., Madison, Wisconsin, USA.
- Park, C.S., and Augenbroe, G. (2003), "A Preliminary Survey on Maintenance Performance Indicators and Planning Steps," Survey on Maintenance Performance Indicators and Planning Steps, Georgia Institute of Technology, Atlanta, USA.

- Pati, D., Park, C.S., and Augenbroe, G. (2009a), "Facility Maintenance Performance Perspective to Target Strategic Organizational Objectives", *Journal of Performance for Constructed Facilities*, 24(2), 180-187.
- Prakash, P. (2005), "Effect of indoor environmental quality on occupant's perception of performance: a comparative study," M.S. Thesis, University of Florida, USA.
- Preisner, W.F.E. (1995), "Post-occupancy evaluation: how to make buildings work better", *Facilities*, 13, 11, 19-28.
- Saidi, M. (2007), "Developing a user-perception assessment tool for health facilities in South Africa," *Proceedings of the second Built Environment Conference*, Cape Town, South Africa, 17-19 June, 2007, pp. 12.
- Shohet, I.M. (2006), "Key Performance Indicators for Strategic Healthcare Facilities Maintenance," *Journal of Construction Engineering and Management*, 132, 4, 345-352.
- Shohet, I.M., Lavy-Leibovich, S. (2004), "Healthcare facilities management: State of the art review", *Facilities*, 22, 7/8, 210-220.
- Slater, S.F., Olson, E.M., and Reddy, V.K. (1997), "Strategy-based performance measurement," *Business Horizons*, 40, 4, 37-44.
- State Council of Higher Education (2001), *Higher Education Facilities Condition Reporting Guidelines*, Richmond, Virginia, USA.
- Teicholz, E., and Edger, A. (2001), Facility condition assessment practices, Retrieved on 15 August 2009 from http://www.graphicsystems.biz/gsi/articles/FacCondAssessPrac_IFMA_01Sept.pdf.
- Tucker, M., and Smith, A. (2008), "User perceptions in workplace productivity and strategic FM delivery," *Facilities*, 26, 5/6, 196-212.
- Turpin-Brooks, S., and Viccars, G. (2006), "The development of robust methods of post occupancy evaluation," *Facilities*, 24, 5/6, 177-196.
- USEPA (2009), The inside story, a guide to indoor air quality, retrieved from <http://www.epa.gov/iaq/pubs/insidestory.html>.
- USGBC (2009), LEED Reference Guide for Green Building Operations and Maintenance, For the Operations and Maintenance of Commercial and Institutional Buildings, 2009 Edition.
- Varcoe, B.J. (1996), "Facilities performance measurement", *Facilities*, 14, 10/11, 46-51.
- Watson, J.R. (2009), Real property Inventory (RPI) and asset management (RPAM), retrieved on 15 August 2009, from <http://www.wbdg.org/om/rpi.php>.
- Zimring, C. (2010), Facility performance evaluation, Whole Building Design Guide, retrieved from <http://www.wbdg.org/resources/fpe.php>.

1.2

THEORETICAL UNDERPINNINGS OF THE FEEDER FACTORS INTEGRATION FRAMEWORK

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ABSTRACT

Purpose: This paper presents the theoretical underpinnings of the '*Integrated Feeder Factors Framework (I3F)*'. I3F is intended to assess the maturity of FM industry (FMI) at a country level.

Background: The paper discusses the tenets of I3F as a tool for assessing maturity of the FMI at country level. It identifies the key factors driving the development and maturity of FM industry. It further elaborates on the assumptions, assessment procedures and level of maturity assessed under I3F.

Approach: In the identification of the key factors for the maturity of FM, data were gathered through intensive review of literature. The analysis was performed using content analysis.

Results: This is a theoretical paper which articulates the conceptual development of I3F and gives a step by step approach for analysing the maturity of the FM industry within a country. Empirical data to validate I3F is the subject of another paper.

Practical Implications: I3F is an approach which can be used as a road map for setting development plans for FM industry within a country. It gives an opportunity to FM stakeholders to identify the performance of each of the key factors which contribute towards the maturity of FM.

Research Limitations: This is a theoretical paper and the assumptions made in it have to be tested before the final conclusions on the applicability of the framework can be made. However, the factors and the assumptions were validated by 55 FM experts from various parts of the world.

Originality/Value: This is the first research which articulates the theoretical underpinnings of the I3F. The results are useful to FM stakeholders and policy makers.

Keywords: Feeder Factors, I3F, Facilities Management Industry Maturity

1 INTRODUCTION

This is a theoretical paper intended to articulate the fundamentals of “*Integrated Feeder Factors Framework or I3F*”. The framework is developed as a tool for assessing maturity of the FM industries in various countries. It is developed based on the intensive review of existing published literature. In essence, the framework provides a road-map to help stakeholders in Facilities Management (FM) to chart plans for the progression and longevity of the industry. The research breaks the norm by extending the assessment of maturity beyond organisation levels.

Assessing an industry maturity provides a base for interpreting, ascertaining and comparing industry capabilities at micro (organisation) and macro (country) levels (Mettler and Rohner, 2009; Wills and Rankin, 2010). At the micro level, maturity has been used in benchmarking the capabilities and performance of an organisation against the best practice or other peers within the industry (de Bruin et.al, 2005; Wills and Rankin, 2010). Wills and Rankin (2010) suggest that the maturity of an industry with respect to its key practices informs the stakeholders of how effective and efficient the industry is in achieving its objectives. A high level of maturity tends to indicate an effective deployment of scarce resources in response to changing technological and societal environment (Marshall and Mitchell, 2002).

In order to meet the demands and expectations of a dynamic, increasingly global business world, FM professionals has to develop state of the art capabilities which will enable them to operate effectively and efficiently. The development of new skills and capabilities in FM has been a challenge, even for developed countries. Thus, this paper uses literature in responding to questions such as; what factors are essential in elevating the FM industry to the next level? How can these factors be organised to realise maturity? How do we know the next mature state for the FM industry?

2 STATE OF THE ART

The concept of maturity is not new for the FM industry. There are two reasons to support this statement. In the first instance, maturity was one of the issues discussed in the first EuroFM conference on Facilities Management held in Glasgow in 1990. The conference objectives, among others, were set with the aim of developing facilities management research and education into a “*more mature activity*” (Alexander et.al, 2004). The symposium pointed out that the connection between education, research and practice is a critical means of steering FM education and research into maturity. In the second instance, there have been efforts to measure FM maturity based on a number of criteria. The most dominant FM maturity measures involve the use of market data (macro-level) or processes within an organisation (micro-level).

Market data tends to measure maturity based on the contribution of FM as an economic activity to GDP and the number of employment created (Gunton, 1999; Moss, 2007; Teichmann, 2009; Jensen, 2010a and Duchamps, 2010). Also, maturity has been estimated based on the volume of in-house and outsourced activities (Teichmann, 2009 and Jensen, 2009; 2010a). However the use of market data to assess FM maturity has been criticized due to its inconsistent results. In the United Kingdom (UK) for example, Moss (2007) indicated that FM industry was estimated to contribute between £4.5 billion to £187 billion within the same time span. Jensen (2010a) has also shown that studies carried out to estimate maturity in Nordic countries had come up with different maturity levels. He observed that while Cap-Gemini had

classified Sweden as the most developed FM market; Toni et.al. (2010) identified Denmark as an advance market. Both Moss (2007) and Jensen (2010a) urge that FM market data should be used with caution in determining the level of maturity due to possible discrepancies. The influence of process capability maturity models (CMM) has also been extended to the FM industry (Turner, 2009, Amaratunga et.al, 2008 and Hinks, 1998).

CMM based models consider FM maturity by evaluating the performance of internal capabilities within organisations. Since these models deal only with organisational performance attributes, it is difficult to apply them to a wider country context which is the intention of this paper. Also it is difficult to assess maturity of FM as an industry based on internal processes alone due to its diversified nature. Assessing the maturity of an industry requires an inclusive framework taking into consideration a range of macro factors.

3 APPROACH IN THE IDENTIFICATION OF MACRO FACTORS

3.1 Identification of factors influencing the development of FM Industry

The foundation for the identification of the six factors was the understanding that FM is an industry (Banyani and Then, 2010). The classification of FM as an industry is due to its ability to meet four attributes of an industry (i) provision of products and services (ii) generation of income & creation of employment (iii) systematic performance of the activities & prospects of continuity, and iv) ability to tend, preserve & improve its stock of resources. In identification of the factors essential for the development and maturity of the FM industry, hermeneutics and content analysis were used. The processes involved in the identification of the factors were broken down into the 'pre-understanding' and 'understanding' phases:

3.1.1 *Generic pre-review of publications in Facilities Management: Pre-understanding*

At the pre-understanding stage, a review of FM literature was conducted with the purpose of identifying essential factors that influence the development of FM industry within a country. The research reviewed a total of 66 publications (books, conference papers and journal papers) and two official websites. The choice of the sources was based on purposive sampling aimed at identifying sources with rich information on the subject matter. In specific terms the identified factors were supposed to be related or contributing to the development of the above four attributes of an industry. Out of these sources 43 (65%) were found to comply with the set criterion. The in-depth review of the 43 sources was conducted for the purposes of identifying a link between outcomes of the FM literature review and the four attributes of an industry.

3.1.2 *Creation of themes and Key words from original text*

The process of analysing the publications was performed using a three column table. The paragraphs containing text showing discussion of factors influencing the development of FM was the starting point of the analysis. The original content of the each of the publications was recorded in verbatim in column 2 of Table 1. The first column had the author's name and the year of publication. Each of the words within the paragraphs were analysed to identify the context within which they were used. The identified *key words* were recorded in the last column of Table 1.

In some situations the identified paragraphs had used the *key words* in the needed form, while in others the interpretation of the context was conducted by researchers. The interpretation of the words required the pre-understanding of the context within which they were used. For example Alexander (1996) had a long paragraph which proposed the roles which ought to be

played by the professional bodies. Among the roles, he proposed the professional bodies to ‘*create the condition to promote advancement of the discipline*’. These conditions have been interpreted in this study as “*the FM Business Environment*” which is essential for the recognition and longevity of the FM industry. Likewise, words such as *FM profession* (Park, 1998); *the field of FM* (Cairns and Beech, 1999; Nutt, 1998), *practitioners* (Alexander, 1996); *expertise* (Grimshaw, 2001) were interpreted to mean the “*Practice of FM*.”

Table 1: Distribution of the factors in the chosen FM Literature

S/N	Author	Factors					
		Practice	Market	Education	Environment	Professional bodies	Research
1.	Then and Akhlaghi, 1992	✓	✓	✓			✓
2.	Park, 1998	✓	✓	✓		✓	
3.	Clark and Hinxman, 1999	✓	✓	✓	✓		
4.	Cairns and Beech, 1999	✓	✓	✓			
5.	Lomas, 1999	✓	✓	✓			✓
6.	Nutt, 1999	✓		✓			✓
7.	Nutt and McLennan, 2000	✓	✓				✓
8.	Grimshaw, 2001	✓	✓			✓	✓
9.	Lord, et.al. 2002	✓	✓	✓		✓	✓
10.	Price, 2003	✓	✓	✓	✓	✓	
11.	Alexander et.al., 2004	✓		✓			✓
12.	Moore and Finch, 2004			✓	✓		
13.	Warren and Heng, 2005	✓	✓	✓	✓	✓	
14.	Mudrak et.al. 2004	✓	✓				✓
15.	Tonono and Buys, 2008	✓	✓	✓			
16.	Yiu, 2008		✓		✓	✓	
17.	Bon et.al. 1998		✓		✓		
18.	Becker, 1990	✓		✓		✓	✓
19.	De Valence, 2005	✓	✓	✓			
20.	Spedding and Holmes, 1994	✓			✓		
21.	Atkin and Brooks (2005)	✓	✓	✓		✓	
22.	Cotts, et.al., 2009	✓	✓	✓		✓	
23.	Junghans and Olsson, 2012	✓	✓	✓			
24.	Warren, 2006		✓		✓		✓
25.	Hansen, 2012		✓	✓			✓
26.	Jensen, 2012	✓	✓		✓	✓	✓
27.	Nenonen, 2012	✓		✓			✓
28.	Carsten, 2012	✓	✓	✓	✓		✓
29.	Varcoe, 2010	✓	✓		✓		✓
30.	Gunton, 1999	✓	✓				
31.	Moss, 2007	✓	✓		✓		
32.	Gates, 2011	✓	✓	✓		✓	
33.	Jensen, 2009	✓	✓	✓			
34.	BIFM, 2009	✓	✓	✓		✓	
35.	IFMA, 2011	✓	✓	✓	✓	✓	✓
36.	Maliene et.al. 2008	✓		✓	✓		
37.	Alexander, 1996	✓	✓	✓	✓	✓	✓
38.	Nutt, 1998	✓	✓			✓	✓
39.	Sievert, 1998	✓	✓		✓		
40.	Chotipanich and Nutt, 2008	✓	✓		✓		
41.	Owen, 1987				✓	✓	✓
42.	Waheed and Fernie, 2009				✓	✓	✓
43.	Alexander, 2008	✓	✓	✓		✓	✓
Frequency		36	34	28	19	18	21
Rank		1	2	3	5	6	4

The word ‘*practice*’ which has been widely used in FM literature represents people conducting activities related to facilities management as suppliers/providers (in this study these people are referred to as *FM Supply Market*) and those working on behalf of the clients (*FM Organisation Practice*). The roles and responsibilities played by these two groups of people are different. One is a coordinator and representing a buyer while the other is a seller. Thus, the use of the word ‘*practice*’ to refer to all people participating in the industry is not wholly appropriate. Therefore, these two groups are separated and defined independently. While some

interpretations of the concepts used in the earlier text have been performed, care was taken to ensure that the original meaning is not distorted. This is one of the advantages of hermeneutics; it gives flexibility of interpreting to the context of the text while ensuring its originality. The analysis of the publications resulted in the identification of six key words which appeared repeatedly in varying frequencies. The identified key words were *practice*, *market*, *education*, *professional bodies*, *research* and *environment* (Table 1). In an attempt to increase clarity, the factors were renamed *FM Organisation Practice*, *FM Supply Market*, *FM Education*, *FM Professional Bodies*, *FM Research* and *FM Business Environment*.

Understanding of the Relationship between the attributes and the factors

The results of the in-depth review of the 43 published literatures in FM revealed that the four attributes of an industry are output factors. These attributes are the results of other interrelated and interdependent factors. For example; to enable generation of income, an industry requires clear evidence of the existence of a demand side (purchasers of the services) and a supply side (FM suppliers/providers). If one of the two sides does not exist, no transactions will be concluded. Similarly, in-order to create employment, an industry requires the two factors above and the availability of manpower, both skilled and unskilled. Skilled manpower requires specialised training. This suggests that an industry will need training institutions and research centres to be able to develop the required skilled manpower. The relationship between the four industry attributes and the identified essential enabling factors is shown in Figures 1a to 1d.

Figure 1a: Relationships between attribute 'provision of product or services' and the six factors

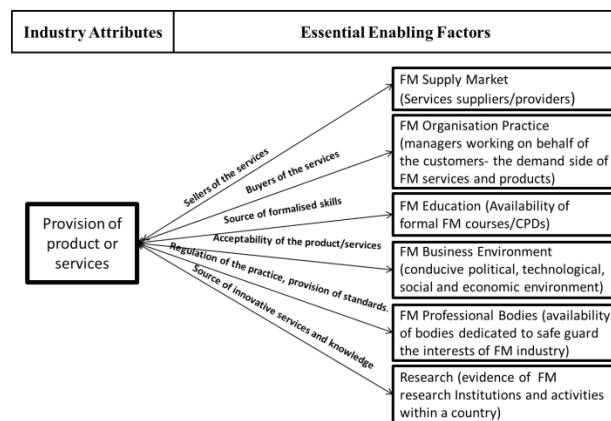


Figure 1b: Relationships between attribute 'Generation of income & creation of Employment' and the six factors

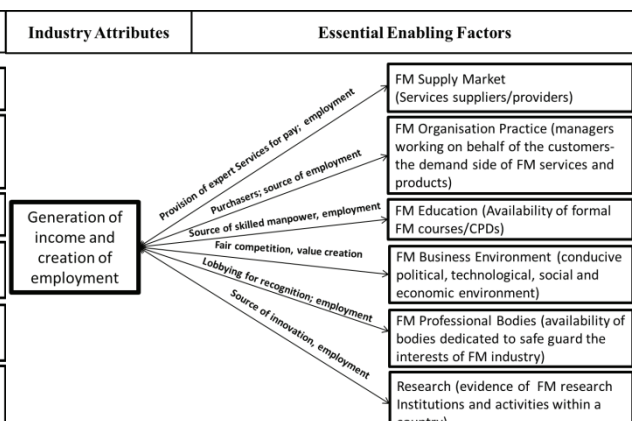


Figure 1c: Relationships between attribute 'Systematic performance of the activities and prospects for continuity' and the six factors

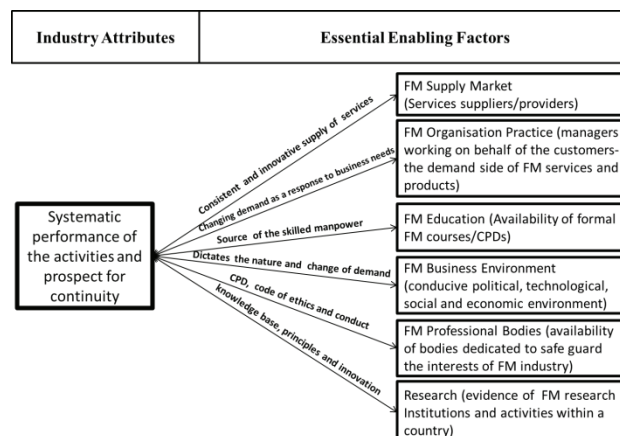
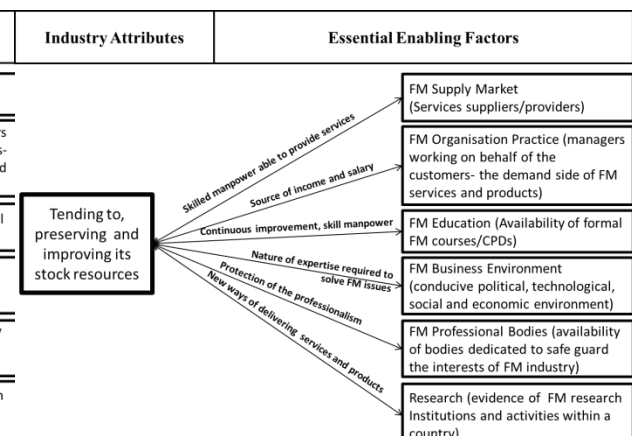


Figure 1d: Relationship between Attribute 'Tending to, Preserving and Improving its Stock of resources' and the six factors



Figures 1a to 1d each illustrates that each one of the four attributes of an industry requires inputs from the six feeder factors. Their existence and interactions contribute to the overall development of the facilities management industry within an economy.

4 JUSTIFICATION AND THEORETICAL UNDERPINNINGS

4.1 Justification for an Integrated Framework for Assessing the Maturity of FMi

Facilities management is a very diverse and broad based industry. Varcoe (2010) considers FM as a fractured industry that borrows its competences from other industries and professions. This diversity in FM points to the importance of integration compared to other professions. The viability of integration in the FM industry is based on the need to make the diverse activities, professions and trades share a common understanding towards their newly chosen area of specialisation. The need for an integrated approach to FM is not new (Then, 2003). The nature of any integration is to make different parts of the system or society interact, connect and validate each other for their mutual benefits. Integration also helps to understand the requirements and capabilities of each of the component parts, i.e. feeder factors. For example, Jensen (2010a) argues that the establishment of *professional bodies* and the need for professionalisation *triggered* the requirement for specialised knowledge (*education*). Earlier on, Becker (1990) noted that many of the ideas embodied in the Cornell's University approach to facilities planning and management (*education*) were included in the IFMA's "Facility Management Curriculum Degree Program" (*professional body*). Hinks et.al (2007), suggested that widespread innovation in FM requires macro-level *cooperation* between sectors of FM supply (*supply market*) and FM demand (*FM Organisation Practice*). Alexander (1996) proposes *collaboration* between academics, research and practitioners (*supply market and organisation practice*), while De-Bruijn et. al (2001) advocate for a *link* between *education* and industry (*suppliers and professionals working on behalf of clients*). The need to link or integrate education, practice and research has also featured prominently in FM literature (McLennan and Nutt, 1992; Nutt, 1999; Lomas, 1999 and Noor and Pitt, 2010).

The lack of integration has been identified as one of the factors that inhibit recognition and development of the FM industry. Gabru (2008) argued that FM in South Africa is not recognised as an independent industry which has resulted in lack of market data, uncertain size of the industry, unknown rate of employment and its contribution to the gross domestic product. Finch (2007) is of the opinion that FM (industry) has not been able to embrace research; this has created a gap between academics and commercial communities. This is also the view held by Varcoe (2010) who observed that FM research is not receiving enough support from the industry.

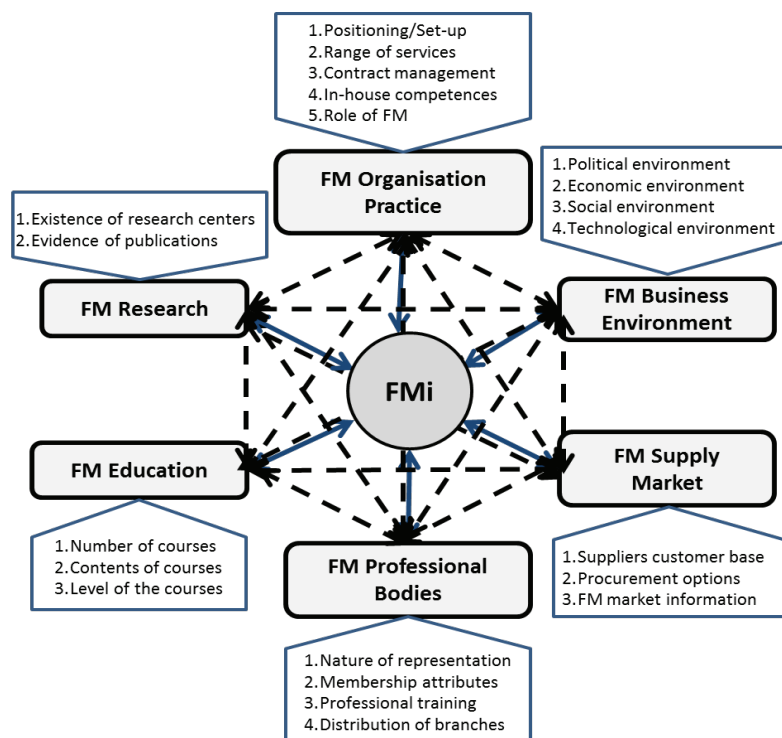
The above review supports the view that it is essential that the factors that enable the FM industry to progress are integrated into a formalised system. It is argued that the overall integration will bring about a sense of involvement, affiliation and co-operation. Thus, it is considered that the feeder factors will strive to achieve their primary objectives while considering the contribution they make to other feeders and the overall industry. Similarly, each feeder factor will make use of the contribution(s) from other feeders for its own development.

4.2 The Integrated Feeder Factors Framework (I3F)

The term 'feeder factors' deduces its meaning from the idea that each factor contributes to the development of the FM industry, and at the same time gives to/and or receives contributions from the other factors. The contribution depends on the dominant progression and integration

level of the feeder factors as assessed using the ‘*feeder factors progression and integration matrices*’ which have been developed as part of this research. Feeder Factors Dominant Progression is assessed based on the Feeder Factors Progression Matrices. These matrices contain tabulated information which represents the evolution of each of the 22 feeder factors criteria shown in Figure 2 from lower to higher level. On the other hand, the dominant integration level is assessed based on the position of the four integration criteria i.e. *co-ordination*, *trust*, *interdependence* and *influence* within the integration matrix. The maturity level of the FM industry within a country depends on the assessed dominant progression and integration levels. The resulting framework is known as *Integrated Feeder Factors Framework* as illustrated in Figure 2.

Figure 2: Integrated Feeder Factors Framework (I3F)



4.2.1 Graphical Representation of the Integrated Feeder Factors Framework (I3F)

The *Integrated Feeder Factors Framework* is represented as a circular model in which the industry (at the centre) is surrounded by the six feeder factors and connected by bold and dotted lines. The bold lines represent the relationships between the feeder factors and the FM industry (Figure 2). The double arrowed bold lines indicate that the feeder factors will contribute into the industry and equally will receive contributions from it. On the other hand, the dotted lines represent the relationships between the feeder factors. These are also double arrowed lines which indicate a bi-lateral relationship between each of the feeders. The interactions (between the factors) show how each feeder factor is related (integrated) to/fed (level of contribution) by the other five factors. The lines used in the graphical representation of the I3F represent both the level of contribution and the interactions of the factors. The construction has taken into considerations the fact that the interaction (integration) between the feeder factors is inherent within the feeding (level of contribution to/or from others) process.

Figure 2 illustrates that each of the feeder factors has a number of criteria. In total there are 22 criteria which were identified to be important in defining the progression level of the individual feeder factors. It is the evolution of these criteria which in turn determine the progression of the feeder factors, their integration and the overall FM industry within a country.

4.2.2 *The Feeding Process*

It has been discussed in the last section that the I3F framework is built on the premises that each of the feeder factors plays two major roles. In the first role, the feeder factors feeds into the industry; while in the second, each feeder factor feeds into each other.

Feeder - FM industry (FMi) Interfaces

In the first role, each feeder factor contributes towards the development of the FM industry independently depending on the degree of its progression and receives a contribution from the industry (as indicated by double arrow lines in Figure 2). The assumption is that the industry will receive a contribution from the each of the feeder factors depending on its level of progression and integration. In countries where the feeder factors are at the lower tier of progression, their overall contribution into the industry is expected to be minimal. The contribution will increase as the industry evolves up the next stage until it reaches the highest level of maturity. The level of contribution from each of these feeder factors will reflect the level of professionalism and capabilities available within a country.

Equally, the level of the maturity of FMi will have a bearing in the contribution it offers to individual feeders. For example, in a country where the state of the industry is immature without specialised FM competences and sophistication; the feeder factors will be at the lower tier of progression or absent in which case the FM activities are likely to depend on traditional FM-related professionals. However, this will change as the FM industry gains a foothold within a country and gradually assumes more responsibilities at both organisational and country level.

Feeder - Feeder Interfaces

In the second role, while feeding into the FM industry, the feeders will also ‘feed’ and ‘receive’ contributions from the other five (5) feeder factors (as indicated by the dotted lines in Figure 2), depending on their progression and their level of integration. If the feeder factors are at the lower tiers of development, their contributions to other feeder factors will also be low. However, when the feeder factors are at the higher levels of development and integration their contribution will be higher. The contributions of the feeder factors to each other will also change as the feeder factors evolve over time due to demands from the other feeders.

4.2.3 *Assessment of Maturity using I3F*

In order to effectively assess maturity of the FM industry; the Integrated Feeder Factors Framework requires the assessor to assess three important facets:


(i) Determination of the ‘*Dominant Progression Levels*’

The ‘*Dominant Progression Level*’ is the level within the feeder factors progression matrices at which a majority of the 22 criteria are located as shown in Table 2. In order to determine the ‘*dominant progression level*’ the assessor has to match the *observed patterns* (The patterns established from the interviews with the local FM experts) with the *predicted patterns* which are evolutionary progression levels summarised in the ‘*Feeder Factors Progression Matrices*’. The matching of the two patterns is essential in establishing a datum or common

level at which majority of the criteria within the feeder factor are found within a country as shown in Table 2. The table shows that a majority of the criteria are found at Level III and a few are found at Level IV of the *Feeder Factors Progression Matrices*. This indicates that in the case country the dominant progression level of the feeder factors is at Level III.

Table 2: Dominant Progression Level

Feeder Factor		Attribute	I	II	III	IV
1. FM Organisation Progress	1.	Positioning			✓	
	2.	Range of Services			✓	
	3.	Mode of Services Procurement			✓	
	4.	Contract Management Approaches			✓	
	5.	In-house Competence			✓	
	6.	Role of FM Organisation			✓	
2. FM Business Environment	7.	Political Environment			✓	
	8.	Economic Environment				✓
	9.	Social Environment			✓	
	10.	Technological Environment			✓	
3. FM Supply Market	11.	Suppliers' Customers Base				✓
	12.	Procurement Options		✓		
	13.	FM Market Information			✓	
4. FM Professional Bodies	14.	The Nature of Representation				✓
	15.	Membership Attributes			✓	
	16.	Professional Training			✓	
	17.	Distribution of Branches			✓	
5. FM Education	18.	Number of Courses			✓	
	19.	Contents of the Courses			✓	
	20.	Level of Courses			✓	
6. FM Research	21.	Existence of Research Centres				✓
	22.	Evidence of Publications				✓
Frequency						




Dominant Progress Level

(ii) Determination of the '*Dominant Integration Level*'.

As above, the assessor is required to determine the '*Dominant Integration Level*'. This is a level in the I3F where a majority of the integration criteria are found. The assessor has to determine this level based on the evolution levels summarised in the '*Feeder Factors Integration Matrix*'. For illustration purposes Table 3 shows an assessment of the *dominant integration level* in one country. The assessment is also based on the predicted and observed patterns. Table 3 shows that the dominant integration level is at Level III.

Table 3: Dominant Integration Level

Criteria	Dominant Integration Level			
	I	II	III	IV
Coordination			✓	
Interdependence				✓
Trust			✓	
Influence			✓	
Frequency	0	0	3	1



Dominant Integration Level

(iii) Assess '*Maturity Level*'

There are four conditions governing the decision on the level of maturity of the FM industry within a country, which are:

- (a) '*The higher the position of the feeder factor criteria within the matrices the higher the progression*'

Individual feeder factors progression is evaluated based on the progress of their criteria as defined by their positions on the *Feeder Factors Progression Matrices*. The matrices are designed with four levels of development ranging from Level I (the least developed) to Level IV (most developed). The assessed '*dominant progression levels*' of each criteria influencing the maturity of the feeder factors are used to map the overall level of progression of the feeder factors within a country. The level of progression of the feeder factors is shown on the vertical axis of Figure 3.

(b) '*The higher the position of integration criteria within the matrix, the higher the integration levels*'

The mutual reinforcement (integration) resulting from the interaction between the feeders as assessed by four criteria namely *co-ordination*, *interdependence*, *trust* and *influence*. The degree of interaction amongst the feeders is evaluated based on integration level as defined in the *Feeder Factors Integration Matrix*. The matrix is designed as four-level incremental stages. Level I of integration is considered to be the lowest and Level IV, the highest. The assessed '*dominant integration levels*' of each criteria influencing the integration of the feeder factors are used to map the overall level of integration of the feeder factors within a country. The level of 'integration' between feeder factors is shown in the horizontal axis of Figure 3.

(c) '*The maturity of FM industry increases as the dominant progression and integration levels increase*'

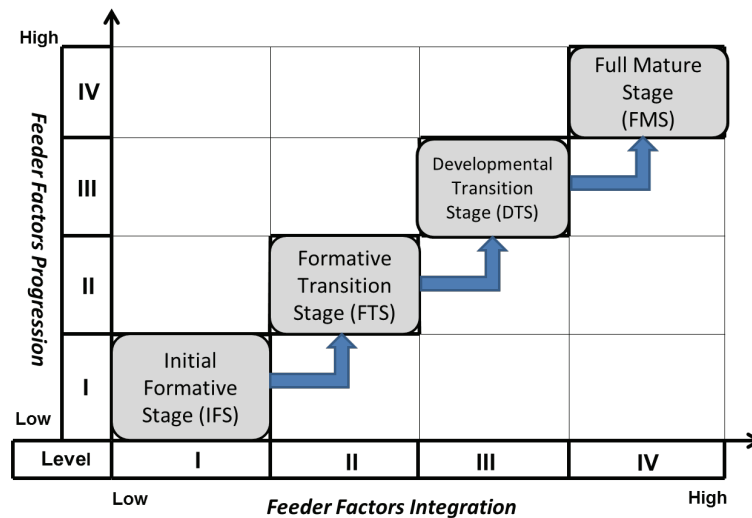
The maturity of the facilities management industry (FMI) increases as the dominant progression and integration levels increase. It is postulated that the progression and integration levels normally match at a certain specific level along the diagonal boxes as shown in Figure 3. At the *Initial Formative Stage* (IFS), both 'progression' and 'integration' levels are assessed at Level I. Similarly, at the *Full Mature Stage*, progression and integration levels are assessed at Level IV. In other words there is a positive correlation between the '*dominant progression levels*' and '*dominant integration levels*'.

(d) '*Higher levels of progression may occur in lower levels of integration*'

The three conditions above suggest that there is a positive correlation between the feeder factors progression and integration levels on one side and the levels of maturity on the other. It is suggested that, the highly developed feeder factors will be found at the higher levels of integration. However, there could be some exemptions of this ideal situation; where lower levels of integration may occur even in the highly progressed feeder factors (especially at middle two *transition* stages in Figure 3). In this case, the progression of the feeder factors may be influenced by individual internal policies, internal motivation and working approaches rather than integration with other factors. On the other hand, it is not possible for the higher integrations to occur at the lower levels of progression due to the fact that *coordination*, *trust*, *interdependence* and *influence* are hard to find at the lower levels of maturity.

After assessing the *dominant progression* and *integration* levels the framework categorises the FM industry maturity into four levels of maturity. The levels varies from the *Initial Formative Stage* (IFS) which defines the progression and integration levels at Level I; *Formative Transition Stage* (FTS), which signifies the dominant progression and integration levels at Level II; *Developmental Transition Stage* (DTS) which indicates that the dominant progression and integration levels are within Level III and *Full Mature Stage* (FMS) which is a fully developed industry showing that the assessment of progression and integrations is at Level IV. These four levels of maturity are shown in Figure 3.

Figure 3: Progression and Integration of FMi



4.2.4 Exceptions to the general rules

- (a) *Exceptions on Dominant Progression and Integration Levels:* In a situation where it is difficult to establish 'dominant progression or integration level' of criteria influencing the feeder factor(s) due to a spread of the opinion over the four levels, the two 'dominant rules' are applied.
- In case one or some of the criteria are within 'dominant progression level' and one or all of the remaining criteria are at higher levels; the factor shall be considered to be in the 'dominant progression level'. For avoidance of doubt; if three criteria are distributed in three progression Levels (II, III and IV) and the 'dominant progression level' of other criteria is at Level III. The 'dominant progression level' of the feeder factor under evaluation shall be at Level III; equal to other feeder factors. For feeder factors with two criteria, if one of them is on the dominant progression level and the other on the higher level, the factor is considered to be within the dominant level.
 - However, if one or some criteria are in 'dominant progression level' and other criteria are in lower levels, the feeder factor shall be considered to be in the 'immediate lower range of the dominant progression level'. In case the criteria are distributed in three progression Levels (I, II and III) under the same 'dominant progression level' used above (Level III). The dominant progression level of the feeder factor under evaluation will be at Level II; i.e. (lower than the dominant progression level).
- (b) *Exceptions in Maturity Assessment:* In case, where 'dominant progression' and 'dominant integration' are at difference levels; the level with 'the highest frequency' will be selected. The level such established will be used to make a decision on the maturity of the FMi.

5 PRACTICAL IMPLICATIONS

Facilities Management (FM), as an organised profession, is relatively new, and is often seen as fragmented in the eyes of existing traditional professions. In many countries economic activities associated with facilities management are still not recognised as a distinct professional sector by clients, senior management or the general public. However, in recent years, statistics relating to the size and scope of facilities management as a distinct economic activi-

ty within a national economy are starting to emerge. In terms of maturity status; FM has been variously described as ‘emerging, developing or mature’ at the same time, even within the same country. This is an indication of a lack of integrative tool to assess the maturity status of the industry. There have been various efforts intended to promote recognition and to elevate the status of FM. These efforts are mainly directed at the assessment of FM maturity within an organisation rather than industry wide. This research contributes a road map for assessing the developmental status of the FM industry within a country using the proposed *‘Integrated Feeder Factors Framework (I3F-‘I Triple F’)*. This was developed as part of a doctoral research project. An understanding of FM maturity level is essential in three reasons: (1) it identifies the performance potential/contribution of the FM industry/sector within a country; (2) it can be used in initiating an informed dialogue between the FM stakeholders and policy makers in considering ways of elevating the status of the FM industry within an economy; (3) assist in devising appropriate strategies, plans and measures for the progressive development and longevity of the FM industry within a country.

6 CONCLUSION

This research has introduced and discussed the fundamentals of the “Integrated Feeder Factors Framework”. This framework is an integrative approach intended to assess the maturity of the FM industry at a country level. The framework and its components were successfully validated by FM experts from various parts of the world and it was tested in five countries namely Tanzania, Hong Kong, Denmark, Norway and the United Kingdom. The results for validation and testing of the framework are the subject of another paper. This research represents a new approach in assessing an industry maturity. Whilst all the necessary assumptions have been considered during theoretical construction, validation and testing phases; it is expected that further empirical studies, especially on a wider scale, can provide more insights on the applicability of the framework. This framework can serve as a basis for evaluating the developmental potential and comparison of FM industries between various countries. It can also be used by stakeholders in FM to identified areas where the industry is not performing for the purposes of continuous improvement.

REFERENCES

- Alexander, K., Atkin, B., Brochner, J., & Haugen, T. (2004). *Introduction to Facilities Management: Innovation and Performance*. Oxon: Spon Press.
- Alexander, K. (1996). *Facilities Management: Theory and Practice*. London: E&N Spon.
- Amaratunga, D., R. Haigh, R., Baldry, D., & Sarshar, M. (2008). Process improvement in Facilities: The SPICE Approach. In K. Alexander, *Facilities Management Processes* (pp. 90-106). Naarden, The Netherlands: European Facility Management Network.
- Banyani, A. M. & Then, D. S. S. (2010) *A Model For Assessing The Maturity Of Facility Management As An Industry Sector. Proceedings of the Fifth Built Environment Conference. Jointly organized by Association of Schools of Construction of Southern Africa (ASOCSA) and The Council for the Built Environment (CBE). 18-20 July 2010, Southern Sun, Elanfeni Durban, South Africa. pp.345-363.*
- Becker, F. (1990). *The Total Workplace*. New York: Van Nostrand Reinhold.
- Cairns, G., & Beech, N. (1999). User Involvement in organisational Decision Making. *Journal of Management Decision*, 37, 14-23.
- De Bruijn, H., Van Wezel, R., & Wood, R. (2001). Lessons and Issues for Defining Facilities Management from Hospitality Management. *Facilities*, 19, 476-483.

- De-Bruin, T., Freeze, R., Kulakarni, U., & Rosemann, M. (2005). Understanding the Main Phases in Developing a Maturity Assessment Model. The 16 Australian Conference on Information Systems (Nov.29-Dec. 2) (pp. 1-10). Sydney: Univeristy of Sydney.
- Duchamps, J. (2010, November 10). *Preliminary Report of the EuroFM Market Data Project, Representing Workspace Facilities & Services*. Retrieved January 20, 2011, from A EuroFM org: <http://www.eurofm.org/library/jose-duchamps-ep-presentation>
- Finch, E. (2007). Editorial. *Facilities*, 25(11/12), 401.
- Gabru, F. (2008, May 09). Facilities Management Needs Recognition as an Independent Industry. *Engineering News*. Retrieved from <http://www.engineeringnews.co.za/print-version/facilities-management-needs-recognition-as-independent-industry-2008-04-11>
- Grimshaw, R. (2001). Ethical Issues and Agendas. *Facilities*, 19, 43-51.
- Gunton, K. (1999, August). FM Industry Sizing Study. *FMA Australia*, pp. 54-55.
- Hinks, J. (1998). A Conceptual Model for the Interrelationship between Information Technology and Facilities management process capability. *Facility*, 16(9/10), 233-245.
- Hinks, J., Alexander, M., & Dunlop, G. (2007). Translating Military Experiences of Managing Innovation and Innovativeness into FM. *Facilities Management*, 5(4), 226-242.
- Jensen, P. (2009). *The Facilities Management Market in Denmark*. Copenhagen: Center for Facilities Management-Realdania Research, Denmark.
- Jensen, P. (2010a). *The FM Sector and its Status in the Nordic Countries*. Copenhagen: DTU Management Engineering.
- Lomas, D. (1999). Facilities Management Development in Hong Kong. *Facilities*, 17, 470-475.
- Marshall, S., & Mitchell, G. (2002). An E-Learning Maturity Model? In A. Williamson, A. K.Gunn, Young, & T.Clear (Ed.), *Proceedings of the ASCILITE, ASCILITE*. Auckland.
- McLennan, P., & Nutt, B. (1992). Facilities Management Research Initiatives. *Facilities*, 10(7), 13-17.
- Mettler, T., & Rohner, P. (2009). *Situational Maturity Models as Instrumental Artifacts for Organisational Design*. ACM.
- Noor, M., & Pitt, M. (2010). Defining Facilities Management (FM) in the Malaysian Perspectives. *ERES 17th Annual Conference, 23-26 June, 2010*. Milano: ERES. Retrieved February 21, 2011, from www.eres2010.org/contents/papers/id2.pdf
- Moss, Z. (2007, December). How Big is FM? *FM Market Intelligence*, pp. 37-39.
- Nutt, B. (1998). Collaborative Research. *Facilities Management World*(8), pp. 11-13.
- Nutt, B. (1999). Linking FM Practice and Research. *Facilities*, 17(1/2), 11-17.
- Park, A. (1998). *Facilities Management: An Explanation* (2 ed.). London: Macmillan.
- Teichmann, S. (2009, September). FM Market Size in Europe. *European FM Insight*(11).
- Then, S. S. D. (2003) Integrated Resources Management Structure for Facilities Provision and Management. *Journal of Performance of Constructed Facilities*. February 2003.17(1), 34-42.
- Toni, A. F., Ferri, A, and Montagner, M. (2010: *Open FacilityManagement – A Successful Implementation in Public Administration*. IFMA Italy.
- Turner, J. (2009). *Notes from the Field*. Retrieved October 20, 2009, from IWMSNews.com/FM: <http://www.iwmsnews.com/2009/03/the-fmo-maturity-model/>
- Varcoe, B. (2010, September). Fractured FM? FM Strategy. *PFM*, pp. 45-46.
- Wills, C., & Rankin, J. (2010). Measuring the Maturity of Guyana's Construction Industry Using the Construction Industry Macro Maturity Model (CIM3). *Construction in Developing Countries*, 15(2), 87-116.

1.3

MAKING-DO – ILLUSION OF EFFECTIVE SERVICE PROCESSES

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ABSTRACT

Purpose: The aim of this paper is to demonstrate what kind of impact incomplete information (i.e. *making-do*) has on a FM service process.

Background: The discussion of the capability of FM to create value for various organisations and individuals is active. Although FM has the capability to create value, recent studies have shown that value is not created efficiently but is constantly interrupted. In addition to interruptions, service processes include a lot of unnecessary work decreasing the efficiency. In this paper, the focus is on the unnecessary work, namely making-do. *Making-do* refers to the activities that are performed although the information is incomplete or not available.

Approach: An in-depth demonstration on *making-do* is presented via a single case study.

Results: The analysis of the case process demonstrates that a great deal of activities became *making-do* because the initial information was incomplete. Also a great deal of next phases were started or prepared long ahead although the outcome of the previous phase was not ready or available. Because of this, employees were performing activities that were not supporting value creation such as structuring and negotiating unnecessary contracts and making unnecessary designs.

Practical implications: *Making-do* provides a new perspective for practitioners and academics in the field of FM to study the productivity of the production phase of FM services.

Research limitations: This research is limited to a single case study. However, similar results in other fields for example in lean construction indicate that making-do is not solely a plague in FM. The theory in other fields has already pointed ways to remove making-do so in the future more constructive research could be done to reduce the making-do.

Originality/value: The new concept, *making-do*, adapted from lean construction is introduced to the field of FM.

Keywords: Lean management, Service production, Waste, Making-do

1 INTRODUCTION

Facilities management (FM) has been identified to add value to organisations and their core businesses (e.g. Jensen et al. 2012, Lindholm 2008, Appel-Meulenbroek and Feijts 2007). However, recent studies have also showed that the value creation phase, where input is transferred into output, has a limited capability to produce that value (Jylhä 2013). In other words, not all of the potential of the added value of FM is transferred in the production phase of the services. In this paper, the focus is on the non-value adding activity called *making-do*. *Making-do* refers to the activities that are performed although the outcome of the previous subprocess is not available (Koskela 2004). In this paper, the aim is to demonstrate *making-do* and its impact on a service process. The demonstration is displayed in a single case study.

The theoretical background of *making-do* is in lean management (Koskela 2004). Lean has many concepts, tools, and techniques, but the central idea is coined with waste minimisation. In general, activities in a service process can be divided into three categories:

- (1) Value adding activities
- (2) Non-value adding activities
- (3) Non-value adding but necessary activities

In general, the proportion of value adding activities is surprisingly low. For example, Hines et al. (2011) argues that only 1-5 per cent of activities add value to the customer. Therefore, it can be argued that most productivity gains can be achieved by minimizing the non-value adding activities, i.e. waste, instead of solely improving the value adding activities. The concept of waste is one of the key fundamentals in lean management.

In this paper, the focus is on waste called *making-do*: its existence and impact on the service process is demonstrated in a facility management context via a case study. In the case study, the service provider is a public utility that manages the governmental premises in Finland. In the case service process, the service provider searches for a solution for their customer, which is centralising its operations in the Helsinki Metropolitan Area. In other words, the service provider searches for suitable premises for its customer. The case process is visualised based on written material and interviews. The visualised process is validated in a workshop with the service provider, i.e. the process owner.

This paper is divided into six sections. After the introduction, the theoretical framework of waste and particularly *making-do* is presented. After this, the research approach and methods are outlined. In the Results section, the making-do is demonstrated and after this practical implications are presented. Finally, conclusions are drawn.

2 MAKING-DO AS WASTE

Koskela et al. (2012) have presented the historical development and diffusion of the concept of waste. The results are interesting. According to their historical review, the concept of waste was developed in the 19th century. At that time waste covered moral and material aspects. In 1880-1930 the concept of waste was flourishing in the scientific management due to

the Efficiency Movement. Waste was a central concept among practitioners and academics. However, after this the concept of waste declined in published literature until it re-emerged with the growing interest towards Toyota Production System. In lean manufacturing, seven types of waste are widely discussed and accepted (Ohno 1989):

- (1) waste of overproduction
- (2) waste of time on hand (waiting)
- (3) waste of transportation
- (4) waste of processing itself
- (5) waste of stock on hand (inventory)
- (6) waste of movement
- (7) waste of making defective products

According to Ohno (1989), the waste of overproduction is the mother of all other waste types, because it generates a lot of other waste. For example, when products are overproduced, a lot of waste activities are conducted when transporting the extra products from a warehouse to another, when the products are moved inside the warehouse, when a product is located in the warehouse without adding any value to anyone, and when products are damaged for example when they are moved.

In addition to the seven traditional waste types, Koskela (2004) has introduced *making-do* as the eighth category of waste in his own discipline, namely in lean construction. Koskela (2004) has adapted *making-do* from Ronen (1992), who used the term *complete kit*. *Complete kit* refers to a set of components or information that are needed to finish a job. Therefore, the job should not be started with an *incomplete kit* (Ronen 1992). Ronen (1992) presented ten shortcomings relating to *incomplete kit*. In the lean production context these can be described as follows:

- (1) **More-work-in-process.** The task is waiting for missing components or information and the production typically gets jammed in a certain phase that creates more unfinished work in the process.
- (2) **Longer lead time.** Because of the missing components or information, activities are often done more than once. This kind of double handling etc. increases lead times.
- (3) **High variance of quoted lead times.** The variance of the lead times increases, when it is not known when missing components or information will arrive.
- (4) **Poor quality and more rework.** Unfinished work causes poor quality. When an unfinished task is waiting for a missing component or information, the outcome of the task can be damaged or the missing component or information is not attached to the outcome properly. This increases rework.
- (5) **Decline in throughput.** When an *incomplete* item or service is in the production process, other items or services have to wait.
- (6) **Decline in productivity.** Due to the *incomplete kit*, double handling, rework, and other waste activities are carried in the production, which decreased productivity.
- (7) **More operating expenses.** Due to the waste activities, unnecessary operating costs are paid.
- (8) **Decline in employees' motivation.** When the missing component or information arrives, that task gets the top priority although the flow might be disturbed after a little while at the next task. Employees are frustrated because they know that they are doing wasted activities and the process does not function optimally.

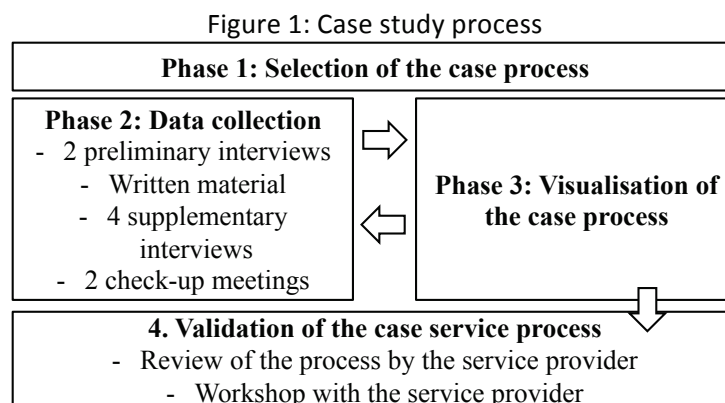
- (9) **Increase in complexity of controls.** To control all the unfinished jobs becomes more and more difficult.
- (10) **Less effort to ensure arrival of the missing kit items.** The initiated job, although it does not include a *complete kit*, gives an illusion that effort is made to get the job done. Unfortunately, after the initiation less effort is aimed to ensure the job is done.

3 RESEARCH APPROACH

The demonstration of *making-do* is conducted via a single case study. In the case study, the service provider is a public organisation that manages and leases governmental premises in Finland. The case organisation has a major role in the Finnish real estate sector: it manages in total 11 000 buildings including 6.5 million sq m of premises.

In the selected case service process, the service provider searched for a solution for a state agency that was centralising its activities in the Helsinki Metropolitan Area (HMA). Initially the customer had premises in more than 10 locations in the HMA. The responsibility of the service provider is to find a solution, i.e., new premises that suit the customer's needs. In this paper, the case process does not include the actual construction or renovation but covers the phase, in which the solution is identified and an agreement is made between the service provider and the customer.

The data collection, analysis, and validation of the results are illustrated in Figure 1. The research process included four phases. In the first phase, the case was selected and defined together with the representatives of the service provider. After this the data collection was initiated by two preliminary interviews. In these preliminary meetings, a responsible employee, who had a central role in the case process, presented an overview of the process. After this, written material, such as memos from planning and project meetings, presentations and contracts, were collected to visualise the case process in more detail.



Data collection (phase 2) and visualisation of the case process (phase 3) were conducted as parallel phases: the visualisation was constructed while the written material was received and read. Because the written material could not cover all the turns in the plot, four supplementary interviews were conducted to fill in the missing spots. Also along the data collection and visualisation, draft(s) of the process display were presented and discussed with the employee who participated in the case process in order to correct possible misunderstandings. After the

process display was conducted, it was validated in the phase four by the service provider and once again by the responsible employee.

4 RESULTS

Next the results are presented. First, an overview of the service process is outlined and a visualisation is provided in Figure 2. Due to the business confidentialities, only an outline of the service process is provided. After this, the *making-do* is demonstrated.

4.1 Overview of the service process

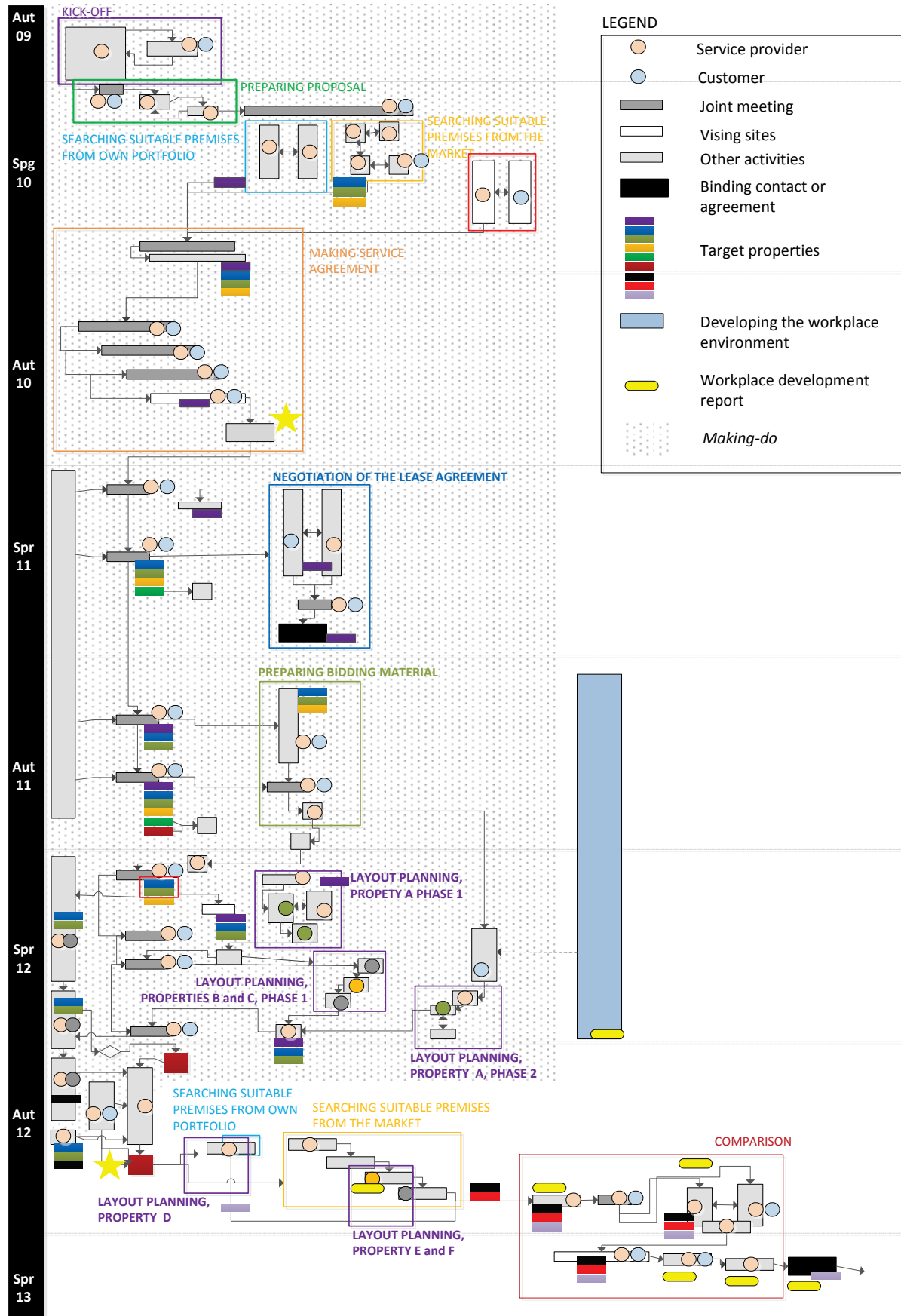
The studied service process spans from late autumn 2009 to early spring 2013 (Figure 2). The process was initiated in late autumn 2009 when a need to rethink the workplace solution was discussed with the customer. Quickly the service provider established a team to find a new solution for the customer. In spring 2010, it was agreed that the activities from ten locations will be centralised into two locations within a walking distance from each other. In line with the previous requirements, the search to find two potential properties from the same area – one from the service provider's property portfolio and one from the lease market – began.

After initially testing and approving of the idea of centralising the activities of the customer into two properties, in autumn 2010 (Figure 2) the service provider and customer negotiated a service agreement where the parties agreed that the service provider will find suitable premises for the customer. After the service agreement was signed, the process moved on in two fronts: a lease agreement was negotiated regarding the service provider's property and more suitable properties were searched and pre-analysed from the market.

A conditional lease agreement to the service provider's property was signed before summer 2011 although it was not clear how many employees were going to be located in the building and who those employees were exactly, i.e., it was not sure what kind of premises were needed and how much of each type of premises was needed. This should have been agreed in the building program but it was not yet conducted due to the organisational changes of the customer. At the same time, the three most suitable premises from the market were selected and bids were asked from the owners. However, at this point, bids were asked with defective information for the same reason as described above: the building program was not conducted yet.

At the beginning of 2012, layout planning was started in the premises with the conditional lease agreement ("Layout planning, Property A, Phase 1" in Figure 2). Layout planning was initiated although the building program was undone. It was agreed that the layout planning would be supplemented after the building program was completed. Also based on the bids, the lease agreement negotiations were initiated regarding two properties from the market. The lease agreement negotiations proceeded to the point where layout planning became a topical issue as well. Therefore, the layout planning was initiated also in these premises although the building program was not conducted. At the same time in late spring 2012, a building program was conducted to cover the properties owned by the service provider. After this, the layout planning was finalised regarding the premises of the service provider ("Layout Planning, Property A, Phase 2" in Figure 3).

Figure 2: Visualisation of the case service process.



In late summer 2012, the needs of the customer were crystallized: the customer concluded that instead of two office locations, they prefer to centralise all activities into one location. Because the previous premises were no longer an option, the service provider started to look for premises all over again. In autumn 2012 new premises were searched for from the portfolio of the service provider and from the market, and layout design and feasibility studies were conducted to compare the financial and functional features of the new options.

Finally, the most suitable option was found and a new lease agreement was signed at the beginning of spring 2013 (the last black box in Figure 2).

4.2 *Making-do in the case service process*

Next an analysis of the making-do is presented according to the shortcomings presented by Ronen (1992):

- (1) **More-work-in-process.** Due to missing initial information, other activities (such as layout planning, negotiations and searching of premises) were started but not finally finished. The missing information caused more work in the process because the tasks could not be finished.
- (2) **Longer lead time.** Due to the missing initial information, a lot of activities were done more than once. For example, the search of premises, layout planning, agreements and negotiations were conducted at least twice (please see Figure 2). In addition, the progress in the tasks that were conducted for the first time was longer than in the second phase because of the missing initial information.
- (3) **High variance of quoted lead times.** In the case, the solution was first attempted to find with *incomplete* information for 2.5 years, but when the information was *completed* the solution was found in six months (please see Figure 2). This demonstrates the variance in the lead times.
- (4) **Poor quality and more rework.** In the case, a lot of the tasks were conducted twice or it was agreed that the outcome of the tasks will be updated later – in terms of lean thinking this means rework. For example, lease agreement, search of premises and negotiations were conducted twice and rework was required in layout planning (in Figure 2 relating to properties A, B and C), bidding, and comparison.
- (5) **Decline in throughput.** Based on the empirical evidence, the authors cannot make strong conclusions relating to decline in throughput. However, based on theoretical analysis it is possible that the other duties of the employees were queued due to the waste activities conducted in the case process.
- (6) **Decline in productivity.** Because of the double work and rework, the productivity in the case process decreased. When the *completed* initial information was received after 2.5 years, it took a bit over 0.5 year to find the solution. Therefore, the waste activities during the first 2.5 years were decreasing the productivity of the service process.
- (7) **More operating expenses.** In addition to the waste activities that were carried out by the employees in the services provider's organisation, also some services (for example, the actual layout planning) were purchased from external service providers. After the initial information was *completed*, work of the employees and the outcome of the purchased service became waste but the expenses remained.
- (8) **Decline in employees' motivation.** For employees it is frustrating to notice that the conducted work becomes waste. However, in the case study the findings are not total-

ly in line with the idea of Ronen. In the case process, the employees were not surprised that some of the earlier activities became waste. Therefore, it cannot be argued that this had an enormous declining impact on employees' motivation although the situation was perceived frustrating.

- (9) **Increase in complexity of controls.** In the case, the complexity increased gradually when the process moved on. In spring 2012, the situation was challenging to control because the initial information was still *incomplete*, the lease agreement to service provider's property was signed so the flexibility was limited, the negotiations with the owners of the external properties were proceeded on a detailed level and the layout planning was conducted with *incomplete* information. This created a complex environment to manage.
- (10) **Less effort to ensure arrival of the missing kit items.** In this case the reaction was the opposite: the employees in the process were very keen on the missing information. Soon after the initial information was *completed*, the process was started all over again.

To summarise, the service provider ended up conducting a lot of *making-do* because the initial information was not correct when the service process began. In practice, almost all the activities that were conducted from autumn 2009 to summer 2012 were *making-do* excluding few exceptions such as strategic workplace management and maintaining contact between the service provider and the customer. This is illustrated in Figure 2 with grey dots.

In addition, a lot of activities were also conducted although it was known that not all necessary information was available to perform the activity defect-free. For example, several layout plans, bids, premise searches, analyses and negotiations were carried out although the information to conduct these activities was *incomplete*.

5 PRACTICAL IMPLICATIONS

On a practical level, the results of this paper encourage to wait until the information is *completed*. Ronen (1992) states that the idea of *completed* information should be part of the implementation of Just-In-Time, Total Quality Management or other major philosophies. According to Koskela (2004), lean management could be one of the philosophies.

In lean construction, the elimination of *making-do* and other waste types has already begun. On a construction site, a method called Last planner© has been developed for production planning and control. According to Ballard (2000), who is one of the key developers of the Last planner© method, a key element in the method is the percentage of assignments completed i.e., how *completed* the information is. This analogy has already been pointed out years ago by Koskela (1999 and 2004) and Ballard (2000). The authors of this paper argue that a similar kind of method is needed in the production of real estate services to minimise *making-do* and other types of waste in order to increase the productivity.

6 CONCLUSION

In this paper the focus was on waste called *making-do*. *Making-do* refers to the activities that are performed although the information is *incomplete* or not available. In this paper, *making-do* was demonstrated in a FM context via a single case study.

The demonstration shows that *making-do* was evident in the case service process. Because activities were started without *complete* information, the employees ended up doing the same things twice, were reworking, and a great deal of activities become waste. Although the results are limited to a single case study, reflecting the results to other service processes can provide insight and understanding on the inefficiency challenges.

In the future, comparative studies in the public and private sector on *making-do* are required to further validate the results. In the long term, it would be interesting to develop a production planning method for FM service processes to remove the *making-do* and other waste types. A successful method with waste elimination characteristics would improve the productivity of FM service processes. This would create value not only for the FM practitioners but also for the customer.

REFERENCES

- Appel-Meulenbroek, R. and Feijts, B. (2007) "CRE effects on organisational performance: measurement tools for management", *Journal of Corporate Real Estate*, Vol. 9, No. 4, pp. 218-238.
- Ballard, G. (2000) "The Last Planner System of Production Control", doctoral dissertation, The University of Birmingham, available at: <http://www.leanconstruction.org/media/docs/ballard2000-dissertation.pdf> (5 December 2013).
- Hines, P., Found, P., Griffiths, G. and Harrison, R. (2011) *Staying Lean - Thriving, Not Just Surviving*, 2nd edition. Cardiff University.
- Jensen, P., van der Voordt, T., Coenen, C., von Felten, D., Lindholm, A.-L., Nielsen, S., Riratanaphong, C. and Pfenninger, M. (2012) "In Search for the Added Value of FM: What We Know and What We Need to Learn", *Facilities*, Vol. 30, No. 5/6, pp. 199-217
- Jylhä, T. (2013) *Creating Value or Waste? Evaluating the Production of Real Estate Services with Lean Thinking*, Doctoral Dissertations 148/2013, Aalto University.
- Koskela, L. (1999). "Management of Production in Construction: A Theoretical View". in the proceedings of the *7th annual conference of the International Group for Lean Construction*, University of California, Berkeley, CA., p. 241-252, available at http://usir.salford.ac.uk/9429/1/1999_Management_of_production_in_construction_a_theoretical_view.pdf (5 December 2013).
- Koskela, L. (2004) "Making-do – The Eighth Category of Waste", in the proceedings of *12th annual conference of the International Group for Lean Construction*, Elsinore, Denmark, available at: http://usir.salford.ac.uk/9386/1/2004_Making_do_the_eighth_category_of_waste.pdf (8th October 2013).
- Koskela, L., Sacks, R. and Rooke, J. (2012) "A Brief History of the Concept of Waste in Production", in the proceedings of *20th annual conference of the International Group for Lean Construction*, San Diego, CA, available at http://usir.salford.ac.uk/23082/1/Koskela%26Sacks%26Rooke_2012_Brief_History_of_the_Concept_of_Waste_in_Production.pdf (5 December 2013).
- Lindholm A.-L. (2008) "Identifying and Measuring the Success of Corporate Real Estate Management", Doctoral Dissertation, Helsinki University of Technology, Espoo.
- Ohno, T. (1989) *Toyota Production System – Beyond Large-Scale Production*, Productivity Press, Cambridge, MA.
- Ronen, B. (1992) The complete kit concept, *International Journal of Production Research*, Vol. 30, No. 10, pp. 2457-2466.

CHAPTER 2

SUSTAINABLE BUILDING DEVELOPMENT

2.1

Comparison of two passive house schools in Norway and Germany

Antje Junghans and Thomas Berker

2.2

Delivering and operating low-energy buildings in France and Sweden

Frédéric Bougrain and Paula Femenías

2.3

Sustainable Development: High Costs offset by Effective Project Management

Olive du Preez

2.1

COMPARISON OF TWO PASSIVE HOUSE SCHOOLS IN NORWAY AND GERMANY

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ABSTRACT

Purpose: The purpose of the paper is to explore the management and use of highly energy-efficient public buildings, with special focus on passive house school buildings. The paper addresses public building owners as well as facilities managers as innovators and early adopters of technology and management solutions for future buildings.

Background (State of the Art): An overview of the state of the art in passive house school building development is presented and studied in detail, with a focus on comparative case studies of the first passive house school buildings finished and taken into use in Germany and Norway.

Approach (Theory/Methodology): The passive house standard and its application for school buildings were defined on the basis of literature research. Germany was identified as one of the first countries to adopt passive house standard to public school buildings. By using German, Norwegian, and English keywords, 70 examples of built passive house schools were identified. Two were selected for in-depth study as they are well documented and have been studied by other researchers: Riedberg School, one of Germany's first passive house schools and taken into use in 2004; and Marienlyst School in Norway, which was finished in 2010. A comparative analysis was conducted to highlight the similarities and differences between the two schools, and in order to discuss the impact of high energy-efficient building technology on public facilities management and user behaviour.

Results and Practical Implications: The paper provides an overview of the state of the art in built and used highly energy-efficient school buildings, and addresses challenges and innovative solutions for facilities management and user behaviour.

Originality/value: The paper contributes to a better understanding of passive house buildings and the challenges related to facilities management and user behaviour.

Keywords: Energy efficient public buildings, Energy management, Facilities Management, Passive house school, User behaviour

1 INTRODUCTION

Passive house schools are highly energy-efficient public buildings. In Europe according to climate and energy policies and a package of binding legislation, the numbers of such buildings are expected to increase in near future. The EU's 20-20-20 strategy defines three targets for an integrated approach to climate and energy policies until 2020: a 20% reduction in EU greenhouse gas emissions from 1990 levels; raising the share of EU energy consumption produced from renewable resources to 20%; and a 20% improvement in the EU's energy efficiency (European Commission, 2007). The Energy Performance of Buildings Directive (EPBD) promotes the development of almost zero-energy buildings: 'By 31 December 2020, all new buildings shall be nearly zero-energy consumption buildings. New buildings occupied and owned by public authorities shall comply with the same criteria by 31 December 2018' (EPBD, 2010). This directive also encourages the introduction of intelligent metering systems for monitoring energy consumption whenever a building is constructed or undergoes renovation.

The following research questions regarding the management and use of passive house schools are addressed in this paper:

1. What impact does the development and implementation of highly energy-efficient buildings and technical infrastructures have on day-to-day energy management and user comfort?
2. What are the benefits and risks of passive house schools from a facilities management and user perspective?
3. What are the similarities and differences between passive house schools in Norway and Germany, which are countries with different climatic conditions?

2 STATE OF THE ART

In Germany the term 'Passivhaus' (English: *passive house*, Norwegian: *passivhus*) was launched by the Passive House Institute (Passivhaus Institut, PHI), an independent research institute. Since the 1990s, the institute has contributed to the development of the passive house concept. The first inhabited pilot project was a multifamily house in Darmstadt with heating energy consumption below 12 kWh per m² per annum (PHI, 2012a). The PHI defines the passive house standard as energy efficient, comfortable, and affordable. Energy consumption for heating is less than 15 kWh/m²/p.a. Passive houses use solar energy, internal heat sources, and heat recovery. During the warmer months of the year, passive cooling is achieved through strategic shading. The thermal comfort of the indoor environment benefits from little variation between the temperatures of internal surfaces and air. Passive houses have highly insulated building envelopes, including the roof, flooring, exterior walls, and special windows. Ventilation systems with heat recovery supply constant fresh air and recirculate the heat contained in the exhaust air (PHI, 2012b). Important benefits of passive house buildings are energy savings between 75–90% compared to existing building stock: the latter have an average annual energy consumption of 200 kWh/m²/p.a., whereas passive house schools have less than 23 kWh/m²/p.a. Furthermore, the savings should not only be considered in terms of energy consumption, but also in energy costs and environmental impact (Pepper et al., 2007; PHI, 2012b).

The Norwegian Government plans to tighten the energy requirements in the building code to passive house level by 2015 and almost zero-energy level by 2020 (Ministry of the Environment, 2012). A newly developed passive house standard for non-residential buildings in Norway (NS 3701:2012) has specified and developed further the original PHI approach (PHI 2012a; PHI 2012b) according to differing climatic, building construction, and architectural contexts. In Norway, the certification of buildings as conforming to either passive house or low-energy standard includes minimum requirements for: heat losses; cooling demand; heating demand; energy supply, and technical infrastructure as parts of the building, components, and systems, as well as air tightness of building envelope. Passive house criteria defined by the Norwegian standard are applicable to 11 different types of non-residential buildings, including school buildings. The following requirements for the certification of passive house school buildings in Norway have been specified on the basis of a building size of more than 1000 m², an annual mean temperature above 6.3 °C (in Oslo), and a maximum outdoor temperature of 20 °C:

1. The heat losses for transmission and infiltration are not more than 0.40 W/m²K
2. The building is designed in a way that thermal comfort is achieved with very low energy demand for cooling of indoor air and/or supply air. The energy supply for cooling is 0 kWh/m²/p.a.
3. The heating demand for spaces (*romoppvarming*) and ventilation (*ventilasjonsvarme*) is not more than 20 kWh/m²/p.a.
4. The passive house must meet requirements for energy supply in accordance with the regulation on technical requirements for construction (building code)
5. The minimum requirements of building parts such as U-values for windows and doors ≤ 0.80 W/m²/K, components, systems, and leakage rate less than 0.60 h⁻¹ are achieved (NS 3701:2012).

The management and use phase of buildings – facilities management (FM) – is defined as: ‘The integration of processes within an organization to maintain and develop the agreed services which support and improve its primary activities’ (EN 15221-1, 2007). The passive house school building, including all technical infrastructures, building parts, components, and systems are referred to as the school facility. Energy management is a subdomain of FM, and integrates all relevant facilities services to ensure that ‘Client demand for utilities (technical infrastructure) is satisfied by services resulting in a comfortable climate, lighting/shading, electrical power, water and gas’ (EN 15221-1, 2007). The main area of responsibility is visible in the operational and utilization phase of a building. Regular monitoring of the power consumption, benchmark analysis, and identification of savings potential and its implementation are essential working areas in energy management (Junghans 2012).

An FM ‘client’ is a composite group consisting of building owners, users, and end-users at all levels of an organization. Often, the organization as an aggregate is addressed as the user of a building. In this sense, the organization as such has specific demands and resources. However, a building interacts directly with its occupants, and it cannot be presupposed that the organization’s demands and resources will coincide with the demands and resources that each of its members has in relation to their daily interactions with the building. Rather, especially in relation to energy consumption, there is a wide array of different ways of using buildings. Studies showing this kind of variety of uses are often conducted in relation to residential buildings (e.g. Wilk & Wilhite 1987; Aune 2007), but there are clear indications that similar processes are in operation at workplaces (Berker 2011; Heerwagen & Diamond 1992). The

heterogeneity of users and the required interaction between ‘user demand’ and ‘facilities services’ are the main reasons to add an explicit user perspective to the FM perspective.

3 APPROACH

By using German, Norwegian, and English keywords, 70 passive house school projects were identified from publicly accessible sources. The information relating to the projects was then structured according to the following criteria: name of the school, year of completion, country in which the school was located, and sources of further information.

The sorting on the basis of country of location revealed the following distribution of passive house schools in Europe: Germany (36 schools), Austria (22), Norway (6), France (2), UK (2), Belgian (1), and Netherlands (1). This geographical distribution in our sample clearly reflects that the passive house standard has its origins in German-speaking countries.

The sorting on the basis of year of completion revealed that 46 documented passive house schools were completed between 2009 and 2013, 18 were completed between 2005 and 2009, 4 were completed before 2005, and 2 were expected to be completed in 2014/15. These results correspond well to the general trend towards an increasing number of passive house buildings in Europe.

The oldest, well-documented, passive house school projects were examined more closely because they had been in the operation and use phase for a number of years. Projects in Norway and Germany were selected as examples to describe how the passive house standard is applied in countries with different climatic conditions. The following list was developed for a comparison of the selected schools, and considers criteria of the above-mentioned definitions and the key issues for further development of passive house school building project documentation:

1. Building history, ownership, management, and use
2. Location and climate conditions
3. Architectural design and heated floor area
4. Energy supply and consumption
5. Challenges for management and use.

The following analysis is based on secondary analyses of studies conducted in the use phase of the two schools. More specifically we draw on the metrological study and analysis (Peper et al., 2007) for Riedberg School. The main source for Marienlyst school is a quantitative survey (employing the ‘Örebro Questionnaire’, N = 340) in conjunction with 23 semi-structured interviews with teachers, pupils and facilities managers conducted in 2011 (Thunshelle & Hauge 2012).

4 RESULTS – COMPARISON OF MARIENLYST AND RIEDBERG SCHOOL

In Norway, the construction of Marienlyst School, a lower secondary in Drammen, was finished in 2010 and the building has been in operation and use since then. Riedberg School, a

primary school and preschool in Frankfurt am Main, is considered Germany's first passive house school and has been in management and use since its year of completion in 2004. Both school projects are well documented and have been considered as highly energy efficient buildings within research and demonstration projects in Norway and Germany (Peper et al., 2007; Dokka & Andersen, 2012).

4.1 Building history, ownership, management, and use

Drammen Eiendom KF, the real estate and FM department of Drammen Municipality represents the owner of Marienlyst School and is responsible for the management of the school building. Marienlyst School is one of 21 schools making up the total 300,000 m² of public buildings owned by Drammen Municipality. The general field of responsibility of the real estate and FM department includes operation, maintenance, modernization, new building development and realization, purchasing, selling, leasing, and renting. In 2013 the main users of Marienlyst lower secondary school (*ungdomsskole*) were 510 pupils in the age range 13–16 years, in 8th to 10th grades. The school had 60 employees. In 2008, the Norwegian architectural firm div.A arkitekter was engaged with the project planning after they had won the first prize in an architectural competition that had five participants. During the competition there were no requirements to meet passive house standards, but the decision to adhere to the standards was made after the construction work on the new school had started. However, the compact body of the building has since proven to be very suitable to meet the stringent energy requirements associated with the passive house standard (Dokka & Andersen, 2012; Hahn, 2013) (Drammen kommune¹).

The primary school and preschool in Frankfurt am Main Riedberg is well known in Germany as an example of a passive house school. The Passive House Institute was involved in the planning and implementation phase of the school and has since conducted research on behalf of the City of Frankfurt am Main. The planning and construction phase of Riedberg School started with an architectural competition in 2001. The school was finished and taken into use in November 2004. In 2007 Riedberg School had 400 pupils (in the age group 6–10 years) in 16 classes belonging to 1st to 4th grades. In addition, 100–125 children, in five groups, attended the preschool (Peper et al. 2007). The school is owned by the city of Frankfurt am Main, represented jointly by the Stadtschulamt (school department) and the Hochbauamt (building construction department).² The Stadtschulamt is responsible for the facilities management of the city's schools, whereas the Hochbauamt is responsible for the energy management and maintenance of the buildings. In 2001 the architectural office 4a Architekten, in Stuttgart, won the first prize in an architectural competition, and was engaged to design and plan the construction of Riedberg school³ (Peper et al. 2007; Bretzke, n.d.).

4.2 Location and climate conditions

Marienlyst School is located in the centre of Drammen, 40 km west of Oslo. The school is close to a sports park (Marienlyst idrettspark) and a public swimming pool (Drammensbad) (Hahn 2013). Drammen has an annual mean temperature of 6.3 °C. The average temperature

¹ <http://www.drammen.kommune.no/Om-kommunen/Virksomheter/Skole/Marienlyst-skole/> (accessed 30 September 2013).

² [http://www.frankfurt.de/sixcms/detail.php?id=5343481&_ffmpar\[_id_inhalt\]=51913](http://www.frankfurt.de/sixcms/detail.php?id=5343481&_ffmpar[_id_inhalt]=51913) (accessed 13 November 2013)

³ http://www.4a-architekten.de/projekte/4_kultur/riedberg/e_riedberg.htm (accessed 13 November 2013)

in summer is 20 °C and in winter it is −1 °C. The warmest months are July and August, with the highest temperatures reaching 26°C and the lowest temperatures falling to around 13 °C in the evenings. The coldest month is January, with an average temperature of −4.7 °C.⁴

Riedberg School is situated in Riedberg, a northern suburb of Frankfurt am Main. Frankfurt am Main has an annual mean temperature of 9.7 °C and a horizontal irradiation of 1046 kWh/m². The typical heating period begins 1st October and ends on 30th April. The average temperatures measured in the heating periods in 2005–2006 and 2006–2007 were 4.3 °C and 8.5 °C respectively (Peper et al., 2007).

4.3 Architectural design and heated floor area

Marienlyst School is a compact building comprising three stories. Due to natural changes in the ground level on site, the first floor is partially buried and includes a large common room for the whole school, as well as wardrobes, special rooms, and a library. The second floor has a community area with a café, workplaces for teachers, administration offices, and special rooms. The third floor consists mainly of compact student areas and group rooms. The architectural design is characterized by the clear and simple building volume with a lot of variation in architectural expression, form, and use, of materials. The school has a heated floor area of approximately 6.450 m² (div.A arkitekter, 2010; Dokka & Andersen, 2012; Hahn, 2013).

Riedberg school building has three stories and is U-shaped in plan. The main users are small children visiting primary school and preschool. In addition, sports facilities are located near the school, on a prominent hillside position. The school has a heated floor area of approximately 5540 m² (Peper et al. 2007; Bretzke, n.d.).

4.4 Energy supply and consumption

Marienlyst School has been built in accordance with passive house standard requirements. The total energy demand is calculated as 75 kWh/m²/p.a. The main energy sources are a district heating system and electricity. The measured net energy demand in the period between 1st July 2011 and 30th June 2012 was 60.9 kWh/m²/p.a., including energy consumption for room heating, ventilation heating, domestic hot water, fans and pumps, lightning, and technical equipment (Dokka & Andersen, 2012; Hahn, 2013).

In the first year of management and use of Riedberg School, the heating energy consumption was documented by the Passive House Institute as 25.4 kWh/m²/p.a. (2005–2006) and in the following year it was 14.5 kWh/m²/p.a. (2006–2007). Several reasons for the difference in consumption between the two years were considered: lower occupancy rate, the thermal charge of the ground in the first years after construction, the drying out of the building, and the lack of some optimizations (Peper et al. 2007). The energy consumption certificate (*Energieausweis*) for the building documents a total net energy consumption of 43,3kWh/m²/p.a., which includes an average annual consumption of 29kWh/m²/p.a. for heating (including domestic hot water (2006–2008), and 14.3 kWh/m²/p.a. for electricity (2005–2007)). Wood pellets are used as an energy source for heating and domestic hot water.⁵

⁴ Source: World Weather Online, <http://www.worldweatheronline.com/Oslo-weather-averages/Oslo/NO.aspx> (accessed 28 September 2013)

⁵ <http://www.energiemanagement.stadt-frankfurt.de/> (accessed 12 October 2013)

4.5 Challenges for management and use

Ensuring a good indoor thermal comfort was described by Geir Andersen, technical director of Drammen Eiendom KF, as one of the main tasks of daily management. Andersen (2010) explained that this task includes controlling the temperature and the ventilation air volumes. Internal heat sources and sunshine can cause overheating, which needs to be avoided. Highly developed technical systems are considered as good solutions to such problems. The challenge is to optimize the demand by controlling the heating, ventilation, and lighting. A first resume from the real estate and FM departments' perspective is: 'Build intelligent buildings and operate them intelligently' (Andersen, 2010).

There exists compelling evidence that suggests that school buildings' architectural features have considerable influence on pupils' learning progression (Barrett et al. 2013). In the case of Marienlyst School, a survey conducted among occupants found fewer symptoms related to indoor environmental problems than in an average Norwegian school building (Thunshelle & Hauge 2012). The interviews revealed that especially the pupils felt a certain pride to be part of an environmentally friendly building (Thunshelle & Hauge 2012: 20), a factor which has been reported earlier for residential buildings (Thomsen et al. 2013). While these factors are likely to support learning progression, findings from the same study also support the building manager's impression that the automatic environmental controls could be improved further. In this context, especially temperature control, glare, static electricity, and pressure conditions in the building were mentioned by the building's occupants. The fact that no clear improvements to the problems were reported after two years of occupancy indicates that these problems were not solved by fine-tuning the building's systems.

5 PRACTICAL IMPLICATIONS

The results of the studied passive houses can be used as input for further research as well as for public building owners and facilities managers as innovators and early adopters of future buildings technology and management solutions. The similarities and differences between the passive house schools in Norway and Germany are listed in Table 1. In both countries, Norway and Germany, especially the challenges for management and use seem to be more similar than different, and provide possibilities for further research and development cooperation on an international level.

Table 1: Passive house schools in Norway and Germany: similarities and differences

	Similarities	Differences
4.1 Building history, ownership, management, and use	Both school buildings were the result of architectural competition and were designed and planned by winning architects	Decision to build Marienlyst School to passive house standards was made during the construction phase
Year of construction	Both schools are pilot projects and electively constructed to passive house standards	Riedberg School is 6 years older than Marienlyst School
Ownership and management	Both schools are owned and managed by public authorities	Drammen Eiendom KF represents the owner and have responsibility for the management of Marienlyst School, whereas the management of Riedberg School involves more departments in the City of Frankfurt am Main

User	The schools have a similar number of students and employees	Marienlyst School is a lower secondary school; Riedberg School is a primary school with a preschool
4.2 Location and climate conditions		
Location	Both schools are located in urban environments	
Heating period		The heating period in Oslo (18 September – 8 May) is three weeks longer than in Frankfurt (1 October – 30 April) and the annual mean temperature in Oslo (6.3 °C) is lower than Frankfurt (9.7 °C)
4.3 Architectural design and heated floor area		
Building	Both school buildings have three stories	Marienlyst School has a compact building shape in plan; Riedberg school is U-shaped in plan
Heated floor area		Marienlyst School has a larger heated floor area (6450 m ²) than Riedberg School (5540 m ²)
4.4 Energy supply and consumption		
Energy sources	Both schools use renewable energy sources	Marienlyst School uses district heating sources; Riedberg School uses wood pellets as an energy source.
Total net energy demand (2011–2012)	Both schools have remarkable low demands for electricity	The total net energy demand of Marienlyst School (69 kWh/m ² /p.a.) is higher than that of Riedberg School (43 kWh/m ² /p.a.)
4.5 Challenges for management and use		
Technical components and systems	In both schools, room heating is provided in addition to ventilation heating	
User behaviour	Users in both schools have no responsibility for ensuring a good indoor climate	
Other issues and/or recommendations	At both schools the passive house standard is considered to provide better learning conditions for students and better working conditions for teachers	At Marienlyst School the optimization of the demand, controlling for heating, ventilation, and lighting, is considered a challenge.

6 CONCLUSIONS

What impact does the development and implementation of highly energy-efficient buildings and technical infrastructures have on the day-to-day energy management and user comfort?

A low energy demand for heating has been demonstrated in the studied cases of Riedberg School (Germany) and Marienlyst School (Norway). Efficiency in day-by-day management

is achieved by additional efforts in design, construction materials, and technical systems to reduce the heat losses and make best possible use of the available, natural, and user-related heat sources. In the case of Marienlyst School, additional intelligent technologies such as demand-controlled ventilation and automatic blinds were implemented, whereas the older Riedberg School relies on room-based controls combined with a central time-based control system. To date, experience from Marienlyst School has shown that the added technological complexity has neither increased user satisfaction nor reduced energy consumption.

A common characteristic of both schools is that the additional energy demand for electricity is relatively high and causes total net energy demands of 43–69 kWh/m²/p.a. This finding indicates that possibilities for improvements in passive house standards should be further examined, especially regarding reductions in electricity consumption and the implementation of renewable sources for electric energy provision.

Today, improvements focus on the optimization of a building envelope's thermal insulation. Highly energy-efficient insulation and airtightness of a building envelope increases building and maintenance costs and reduces flexibility for adaptation to changing user demand in a long-term perspective.

From a day-to-day management perspective, the quality and quantity of changing user demands impact the controlling and monitoring of the technical systems. Highly energy-efficient buildings therefore require highly energy-efficient management. This in turn requires high technological standards for building control and monitoring systems, and highly qualified operational and management staff.

REFERENCES

- Andersen, G. (2010), '*Hyggelig å være her!*' *Passivhusskole – utfordringer*, available at: <http://www.lavenergiprogrammet.no/getfile.php/Gamle/Bilder/Personer/Geir%20Andersen,%20Drammen%20eiendom%20KF.pdf> (accessed 13 November 2013).
- Aune, M. (2007), 'Energy comes home', *Energy Policy*, 35, 11, 5457–5465. doi:10.1016/j.enpol.2007.05.007
- Barrett, P., Yufan Zhang, Joanne Moffat, and Khairy Kobbacy (2013). "A Holistic, Multi-Level Analysis Identifying the Impact of Classroom Design on Pupils' Learning." *Building and Environment* 59 (January 2013): 678–689. doi:10.1016/j.buildenv.2012.09.016.
- Berker, T. (2011), "Domesticating Spaces. Socio-Technical Studies and the Built Environment." *Space and Culture* 14 (3).
- Bretzke, A. (n.d.), Planning and construction of passive solar primary school Kalbacher Höhe 15, Frankfurt am Main, available at: <http://www.energiemanagement.stadt-frankfurt.de/Englisch/Passive-house-school-Riedberg.pdf> (accessed 6 October 2013).
- div.A arkitekt (n.d.), 'marienlyst school–Drammen', available at: <http://www.diva.no/?portfolio=marienlyst> (accessed 6 October 2013).
- Dokka, T.H. & Andersen, G. (2012), 'Marienlyst school – Comparison of simulated and measured energy use in a passive house school', Conference Passivhus Norden 2012: From Low Energy buildings to plus energy developments, Trondheim, 21–23 October, available at: <http://tapironline.no/fil/vis/989> (accessed 17 September 2013).
- EN 15221-1 (2007) *Facility Management Part 1: Terms and Definitions*.
- EPBD (2010), 'Energy performance of buildings', Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010, available at:

- http://europa.eu/legislation_summaries/internal_market/single_market_for_goods/construction/en0021_en.htm (accessed 16 September 2013).
- European Commission (2013), 'The EU climate and energy package', available at: http://ec.europa.eu/clima/policies/package/index_en.htm (accessed 18 September 2013).
- Hahn, U. (2013), 'Marienlyst skole', available at: <http://www.arkitektur.no/marienlyst-skole> (accessed 30 September 2013).
- Heerwagen, J. & Diamond, R.C. (1992), 'Adaptations and coping: Occupant response to discomfort in energy efficient buildings', in American Council for an Energy Efficient Economy (ed.), *Proceedings of ACEEE 1992 Summer School on Energy Efficiency in Buildings*, Vol. 10, Washington DC, 83–90.
- Junghans, A. (2012), 'Model for energy efficiency improvement of entire building stocks', *Facilities*, 31, 3/4, 173–184.
- Ministry of the Environment (2012), *Norwegian Climate Policy*. Report No. 21 (2011–2012) to the Storting (White Paper) Summary, available at: http://www.regjeringen.no/pages/38117723/PDFS/STM201120120021000EN_PDFS.pdf (accessed 16 September 2013).
- Peper, S., Kah, O., Pfluger, R. & Schnieders, J. (2007) *Passive House School in Frankfurt Riedberg: Meteorological study and analysis*, Passive House Institute, Darmstadt.
- PHI (2012a), 'Passive House Institute / About us', available at: http://www.passiv.de/en/01_passivehouseinstitute/01_passivehouseinstitute.htm (accessed 16 September 2013).
- PHI (2012b), 'About Passive House – What is a passive house?', available at: http://www.passiv.de/en/02_informations/01_whatisapassivehouse/01_whatisapassivehouse.htm (accessed 16 September 2013).
- Thomsen, J., Berker T., Lappegard Hauge, Å, Denizou, K., Wågø, S. and Jerkø, S. (2013), 'The Interaction between Building and Users in Passive and Zero-Energy Housing and Offices: The Role of Interfaces, Knowledge and User Commitment.' *Smart and Sustainable Built Environment* 2 (1): 43–59.
- Thunshelle, K., and Lappegard Hauge, Å. (2012), *Brukerundersøkelse Om Innemiljø På Marienlyst Skole (Evaluation of Indoor Environment Quality at Marienlyst School)*. Project report. ZEB Project Reports. Trondheim: The research centre on zero emission buildings (ZEB), 2012.
- Wilk, R.R., and Wilhite, H.L. (1985), 'Why don't people weatherize their homes? An ethnographic solution', *Energy*, 10, 5, 621–629. doi: 10.1016/0360-5442(85)90093-3

2.2

DELIVERING AND OPERATING LOW-ENERGY BUILDINGS IN FRANCE AND SWEDEN

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ABSTRACT

Purpose: The goal is to examine how high energy objectives are reached in building projects in France and Sweden and whether these energy objectives have modified the balance of power within the construction business system.

Background: France and Sweden belongs to two different national construction business systems. The organisation of project differs largely between the two countries in terms of responsibilities, expertise and roles when delivering low-energy buildings.

Approach/research limitations: The research includes a presentation of the concept of construction business system. Then, two case studies focusing on the construction and operation of low-energy buildings are exposed. This focus on two projects which are not representative is also the limit of the study.

Originality/value: The cases provide data on low-energy buildings in operation and try to explain the gap between real and expected energy consumption.

Results: Energy and sustainability objectives have led to changes in expertise provided by the actors of the projects and supported a change of power. In both cases the architect has less influence. It is counterbalanced by the emergence of design offices/consultants specialised in energy efficiency. Energy targets are not met at the operation stage after one year of operation. However, in the Swedish case, the performance-based contract provides strong incentives to find solutions in order to reach the energy target established at the design stage.

Practical implications: The cases indicate the need to integrate operators and users at the design stage of any building in order to reduce the discrepancies between expected and real energy performance and to satisfy the European Directive on the Energy Performance of Buildings.

Keywords: Low-energy buildings, Construction business systems, Energy performance

1 INTRODUCTION

The decreases of energy use and greenhouse gas emission are among the main drivers for innovation and change in the building sector. As member of the European Union, France and Sweden are under the influence of European policy. For example, both countries had to implement the 2010 European Directive on the Energy Performance of Buildings which stipulates that *“it is necessary to lay down more concrete actions with a view to achieving the great unrealised potential for energy savings in buildings and reducing the large differences between Member States’ results in this sector.”*

However, despite this common Directive, the way each country follows to reduce energy consumption of buildings cannot be similar since France and Sweden belong to two different national construction business systems.

Winch (2000) considered that there are two levels of analysis within construction business system: the national and the sectoral. At the national level, he identified three business systems: the *Anglo-Saxon*, the *corporatist* and the *“étatique”* systems.

At the sectoral level, the organisation of projects will differ in terms of:

- Conception which *“refers to the organization of the process of design on behalf of the client”*;
- Construction which *“refers to the organisation of the process of execution on behalf of the client”*;
- Control which *“refers to the organisation of third party actors ensuring that the client’s requirements are met”*.

One element can be added to these patterns identified by Winch: operation which refers to the organisation of the process of maintenance and operation on behalf of the user of the building.

There is collaboration between each actor of the system in order to achieve the goal of the client. However, at the same time, there is a competition since each actor tries to influence the system in order to strengthen his own position. Winch (2000, 91) indicates that there are factors *“that allow some actors in the system to become relatively powerful compared to others”*. The *“ability to solve complex problems for the client”*, *“the blessing of the state”* and the *“ability to manage risk for the client”* are three factors identified by Winch.

Based on this framework, the paper will firstly examine whether energy and sustainability objectives have modified the relationships between the actors and the power of each actor. The hypotheses of this paper are that energy and sustainability objectives have reinforced the complexity of building projects and that the actors who can help the client to solve these complex issues will reinforce their power. The second objective is to observe whether this move toward energy performance has been successful and has led to better performance for the building industry.

To answer to this question the paper will present the construction business system in France and Sweden in order to characterise the organisation of building projects in both countries in terms of responsibilities, expertise and roles when delivering high energy objectives. Lessons and practical implications will be based on the results of the two case studies.

2 CONSTRUCTION BUSINESS SYSTEM IN FRANCE AND SWEDEN

2.1 The French construction business systems

The State has a strong influence on the industry through the regulation concerning existing and new buildings. As such, France could represent the “étatique” system identified by Winch. For example, several standards have been developed since the oil crisis and the mid-1970s to reduce energy consumption in buildings. The requirements induced by this change in the regulatory framework led to a reduction of the average energy consumption in residential buildings. Between 1973 and 2005, it decreased from 364.8 kWh/m² to 215.6 kWh/m² (ADEME, 2007).

Following the Grenelle de l’Environnement (a French multi-party debate on the environment involving several bodies) the national energy policy was modified. A new thermal regulation was implemented stating that buildings have to consume more or less than 50 kWh/m²/year (primary energy) in 2013 depending on the climatic conditions that prevail in French regions.

However, this vision of an “étatique” system is mitigated by the influence of three French contractors (VINCI, BOUYGUES and EIFFAGE) which are among the largest construction companies in the world. On the other side, firms with less than 10 employees represent about 93% of the contractors while they concentrate only half of the turnover (CGDD, 2009).

Moreover, the law towards public private partnership (PPP), enacted in June 2004, has brought about renewed interest in PPP. Under this new scheme, design, build, finance and operation are transferred to private sector partners. Despite this law, the vast majority of investments (more than 95%) in the French public service is still procured through conventional means.

In public procurement, the separation between design and construction is the most prevalent framework. Design and Build (D&B), Design or Build and Operate (DB&O) are still exceptions. D&B is possible in case of technical complexity. DB&O is possible since 2012, if it leads to better energy performance.

2.2 The Swedish construction business system

The Swedish construction business system cannot be classified in the aforementioned categories defined by Winch.

2.2.1 The domination of Design and Build

The Swedish construction industry is mainly local and national with a few internationally operating actors. On the production side, the sector is dominated by three large actors. Together they controlled 20% of the Swedish market in 2012 (Sveriges Byggindustrier, 2013). A change process during the 20th century has seen the contractor gaining in power on expense of other actors (Grange 2010). The architect industry reflects the production side with a few large consultancies, a larger number of small consultancies and very few in the segment between these two groups. Compared to other countries, architects and engineers are in a weaker position in being consultants without precise professional responsibilities (Kadefors, 2004). Bröchner et al (2002) describe the Swedish culture in construction as low power distance and low respect for authorities which allows for a strong respect for rationality to be reconciled with a weak role of the experts. The culture is based on a belief in egalitarianism where common sense tends to be valued higher than expertise. The actual power relation is usually perceived as a problematic among architects (Grange, 2010).

Traditional contracts of the type design-bid-build are becoming less common and are often replaced by D&B contracts. D&B contracts are dominating in housing production but less

common in civil works and infrastructure projects, project with higher complexity (Nilsson, 2008). Between 1980 and 1999 the share of D&B contracts in the production of multi-residential buildings increased from 24% to 93% then falling back to 75% in 2007 (SCB, 2010). DB&O contracts have only been tried out in a few projects (Nilsson, 2008).

Public clients are subject to follow agreements on public procurement. A study from 2001 show that 80% of the building projects purchased through public procurement was chosen on the lowest bid. Qualitative differences between architect consultancies and different proposed solutions did not seem to have been given attention by the client in these cases (Lindqvist, 2001).

2.2.2 The introduction of energy objectives in the construction sector

Sweden has thermal requirements of buildings since the 1950s. Since 2006, these regulations have been increasingly strengthened. The last up-dates came into legal force in January 2013 demanding a maximum of 90 kWh/m²/year delivered energy (including heating, hot water, electricity for operation) for housing and depending on the climate conditions.

Last years, Sweden has seen a rapid development of low-energy construction. In 2010, 24% of all new multi-residential buildings in Western Sweden were considered as low-energy i.e. having an energy performance of 25% less energy use than is required by the national building regulations (Wahlström et al, 2011). This progress has been pushed by local environmental policy which often set higher requirements than the national (around 60 kWh/m²/year).. The intensified focus on energy and environmental objectives has pushed all categories of actors in the construction industry to develop competence in this field (Gluch et al, 2013).

3 METHODOLOGY

The first objective is to examine whether energy and sustainability targets have modified the relationships between the actors and the power of each actor. The second objective is to observe whether this move toward energy performance has been successful and has led to better performance for the building industry.

The case study approach appears appropriate since little is known about this phenomenon (Eisenhardt, 1989). As mentioned by Tellis (1997) and Eisenhardt (1989) the selection of the case is one of the most important issues in case study approach. Low-energy building will be a standard in the future. However, in France, the market is still in its infancy and the first projects were launched about five years ago. In Sweden, low energy projects started in the 1970s and since the early 2000s they are becoming dominant. For the comparison, it was necessary to select a modern Swedish example which represents and reflects how the industry deals with actual requirements. For France, it was necessary to select a case among the first low-energy buildings projects in order to get data and feedbacks on the buildings in operation.

The French case study is based on face-to-face interviews with the client, the architect, the design office, the environmental consultant, the operator and the two people who are following the contracts and representing the users of the building. A report completed after one year of operation was also used as complementary source of information.

The Swedish case study is based on a combination of face-to-face interviews with representatives from the client (also the operational unit) and telephone interviews, due to long distances, with the contractor, the architect, and the engineer having the role of energy coordinator.

Some key actors have been interviewed at several occasions. Two earlier reports (not including the operation phase) were also sources of information.

The interviews mainly focused on the organisation of the projects, their origins and goals (mainly energy and environmental issues), the characteristics and impacts of main innovative solutions on the operating costs, the competencies of the different stakeholders, the nature of the contractual agreements, the responsibilities in case of poor performance, the performance of the building in operation and users' involvement during design / construction / operation.

4 FRANCE: THE CONSTRUCTION OF IGN AND MÉTÉO FRANCE HEAD-QUARTER

4.1 Characteristics of the project

The construction of the new headquarters of IGN (National Geographic Institute) and Météo France was decided in 2007 by the Ministry of Ecology, Housing and Transport. The aim was to gather several services scattered everywhere in Paris and its suburbs. The construction was carried out under a public management contract (law n°85.704 laid down the 12th of July 1985). The Ministry, as client, delegated the supervision of the project to its regional division. He was assisted by an environmental consultant who is also in charge of auditing the energy performance of the building after the first and second year of operation.

When the Ministry launched the contest to select the architect, the building was not supposed to be certified and low energy. However, the national multi-party debate on the environmental policy modified the position of the Ministry. During the auditions, the client asked the design team who was finally selected, to modify slightly its project in order to be certified for its environmental performance and to get the label “low energy building”.

The HQE (High Environmental Quality – French environmental assessment system) certification is issued after three audits carried out during key periods (programming, design and construction) in the construction period. The certification relates to the operation management system and the environmental quality of the building. The client must hierarchically define 14 targets in order to create a profile of the environmental quality of the building.

The Ministry decided to focus on four targets which had to reach the level “high performance”:

1. Low site nuisance (environmental management of the building site);
2. Energy management (reduction of energy and greenhouse gas emissions);
3. Maintenance and sustainable environmental performance (the aim is to develop solutions that take into account maintenance issues);
4. Hygrometric comfort.

The cost of the building works reached 30 million Euros for 14 900 m² (and 180 parking places).

4.2 Organisation of the construction process

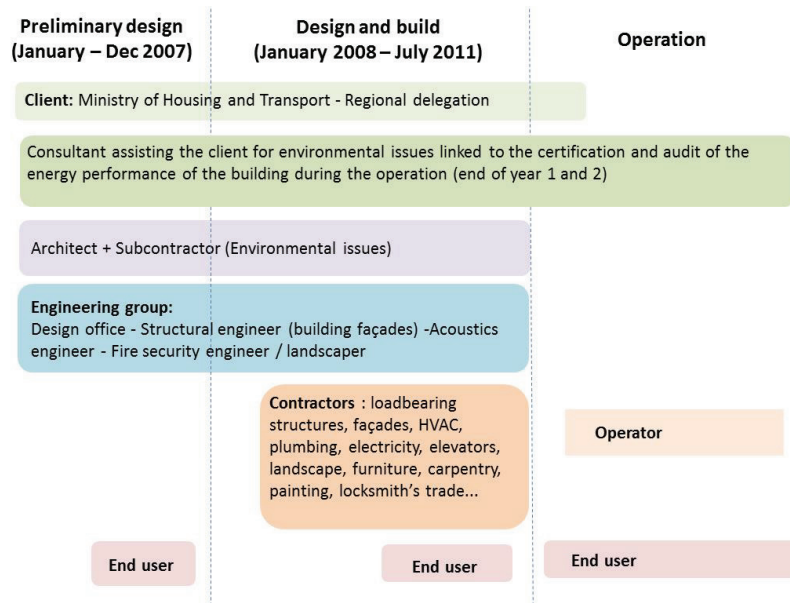
The design team (architect and design office) coordinates the firms in charge of the different batches: loadbearing structure, façades, HVAC, plumbing, electricity, elevators, landscape, furniture, carpentry, painting, locksmith's trade.

The environmental approach modified the organisation of the building process. Preliminary studies were more developed and strongly focused on energy issues. This approach which

was not very usual for most actors was considered as positive since most issues were raised before the launch of building works. However, the administrative tasks were considered as a burden.

The environmental consultant was a subcontractor of the architect. As such, he was not responsible for the final decision and he tended to propose very innovative solutions. Thus, the architect who was not competent for energy issues was not in a comfortable position between the consultant and the design office that preferred to favour traditional solutions.

Figure 1: The actors of the project from design to operation



Several delays were registered at the beginning of the building works. Indeed, the company in charge of the preliminary works was not competent. Moreover, several solutions were quite innovative (the geothermic system, the heating system - capillary tubes for radiant ceilings) and required permanent adjustments. Despite this situation, the building was delivered on time to avoid strong penalties⁶.

The users were not involved during the design process. The people in charge of logistics and representing the users discussed with the architect at the design stage about access control, electrical current and transfer of technical equipment.

4.3 The building in operation: the energy issue⁷

The facility manager is in charge of the maintenance of the building and the follow-up of the energy consumptions. However, his contract is not performance-based. It is more a duty-based contract. In case of poor maintenance, he is not penalised. The facility manager was involved in the project six months after the delivery period since the client forgot to launch a

⁶ Météo France had sold its former headquarter to a Russian property company and it was forced to leave it on time. Otherwise, it had to pay a monthly penalty of 300 000 euros.

⁷ More information linked to the operation stage was obtained. Issues such as the performance of equipment in operation, the satisfaction of the users, the communication towards the users of the building, were raised during interviews. However, the paper focuses on the energy issue.

call for tender on time. Moreover, he was not allowed to optimise the systems for several months since the acceptance of work was not completed.

The building is equipped with a centralised control station that allows the operator to watch over the performance, to optimise the technical installations and to control all energy consumption units. However, the strong thermal inertia of the building makes daily adjustments complex.

After one year of operation, energy consumptions are much higher than expected (table 1). This was due to the inadequacy of the hypothesis retained for dynamic simulations, dysfunctions of the geothermic system and the gap between the theoretical and real use of the building.

Table 1: Comparison between energy objectives and consumptions in operation
May 2012 to April 2013

Uses	Objectives (kWh/year)	%	Consumptions in operation (kWh/year)	%	Gap
Heating	56 428	7.39	327 014	21.32	+ 479,5%
Air conditioning	63 812	8.36	287 017	18.72	+349.79%
Hot water	2 933	0.38	-	-	-
Lighting, office automation	573 461	75.1	743 234	48.46	+29.6%
Ventilation and auxiliaries	66 949	8.77	176 332	11.5	+163.38%
Total without PV	763 583	100	1 533 597	100	+100.84%
Photovoltaic	17 652		12 047		-31.75%
Total	745 931		1 521 550		+103.98%

Source: BEHI (2013)

The geothermic system worked only two months during the first year. Consequently, it was the gas heating system which was the back-up system which was used for the first year. Moreover, when the system was in operation, its energy efficiency was much lower than expected since the pumps that are used for the geothermic system, consume energy.

Moreover, it appears that one floor dedicated to METEO France is in operation 24/7 while the air processing system was supposed to work only five days a week from 8 am to 7 pm. However, the seven floors are inter-dependant. Thus, the air processing system is in operation 24/7 for the part of the building owned by METEO France.

Finally, the large gap for heating is due to the entrance hall. It was supposed to be heated at 17°C. This temperature is fine for employees who cross the hall but not for receptionists who work there. Thus, most of the energy used to heat the building is used for the entrance hall.

5 SWEDEN

5.1 Characteristics of the project

The Swedish Fortifications Agency (SFA) is publicly owned and one of the largest real estate owners in Sweden. Their main role is to supply and operate the Swedish defence estate and their property ranges from statutory protected national heritage buildings to modern purpose built facilities such as airports, naval bases and housing.

SFA has no history of engaging in projects with a sustainability profile. In 2010, two pilot projects for low-energy construction was initiated. The projects are a student accommodation for the training of soldiers, and a rescue station for the military including an administrative part and a depot. The student accommodation was carried out as a D&B contract due to the simplicity of the project while the more complex rescue station was carried out as a traditional design-bid-build contract. This description focuses on the student accommodation for which a penalty was amended the contractor on the energy performance.

The student accommodation consists of two longer building volumes in two levels with individual rooms for 160 soldiers and common areas with smaller kitchens. Stairs and corridors that connect the different parts are not heated but will be heated by surrounding heated space to more than 10 °C and are thus included in the total heated area which is calculated to 4590 m².

The SFA tried out a new method called Sveby in both pilot projects in order to verify the energy demands during the whole process. Sveby stands for 'Standardise and verify energy performance in buildings' (www.sveby.org). This method was developed by the Swedish building industry to interpret and guide functional demands on energy saving in the national building regulation. SFA has an agreement with the Swedish Energy Agency to participate in the development of Sveby.

5.2 The preliminary design

In the preparation of the preliminary design, a specific document was prepared for the energy programme. This was central to the project and also a novelty for the client.

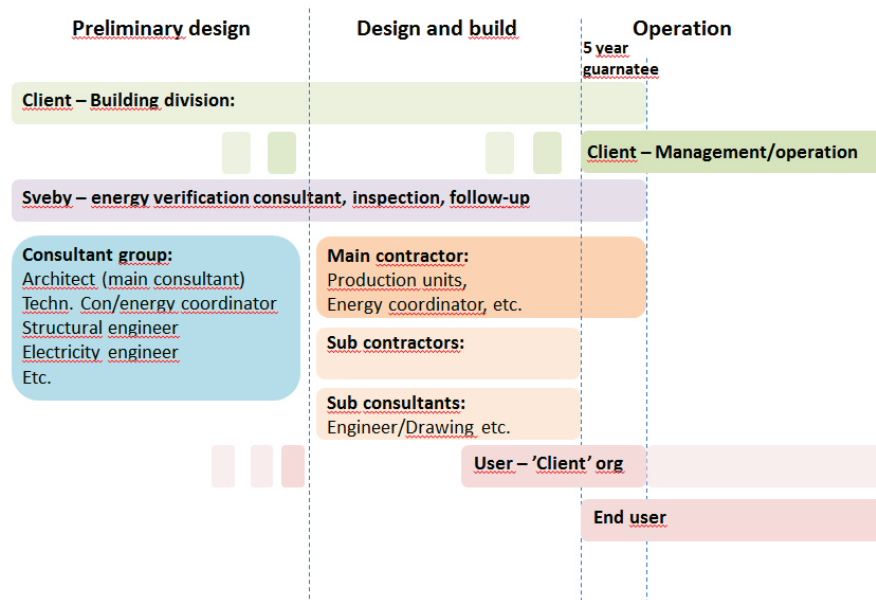
A consultant group directed by an architect was procured for preparing the preliminary design. After a first qualification, the client complemented the tendering process with interviews in a bid to ensure that consultants had the right expertise to reach the energy objectives. The winning architect had a sub-consultant, a technical consultant, as energy coordinator. The energy coordinator had been last in ranking after the first qualification but was granted the project after the interview. The client was satisfied with the interview procedure and found the energy coordinator to be dynamic managing the whole consultant group through a creative process.

Early in the process a specialist from Sveby was contacted to join the consultant group. Initially he provided support as a discussion partner and held training. Later he gave direct input to specifications of requirements in the D&B tender and provided support for control, documentation, and inspection. In the end the Sveby consultant was also contracted to carry out the inspection as it was difficult to find somebody who could do this kind of inspection.

In the early calculations and in discussions with the consultants, the client understood that a higher energy goal than first defined could be reached without larger efforts: 50% instead of 75% of the national regulation. While the initial objective could have been reached by small-

er adjustments to a conventional building, the new objective provided a positive challenge for all involved.

Figure 2: The actors of the project from design to operation



5.3 Design and build – contract and production

A direct consequence of the specific framework programme for energy objectives was that the energy performance must be part of the inspection of the building. Energy performance as a juridical part of a contract is not the normality in Swedish construction projects. Further, the D&B contract was designed with a penalty on the energy performance but without a reward, as public clients are not entitled to give rewards. The main contractor is also responsible to follow-up the energy performance during five years from the inspection. The penalty was defined as:

A penalty will be demanded at the 2-year inspection if objective of not increasing the energy use by 50% of the building regulation (55 kWh/m²/year) has been fulfilled.

The contractor is given the opportunity to within 3 month from the 2-year inspection declare performed actions, if not a penalty is demanded as of 1 SEK (~0,10 €) per increase of 1 kWh/m²/year multiplied with 30 years (theoretical life time of the building).

Because of the crisis on the construction market and the prestige to win the bid of this low-energy project, the client received offers that were lower than expected. He selected the lowest bid. The contractor engaged an engineering company to make the final design and had an employee from the technical department of their HQ as the energy coordinator.

The high energy performance required a very air-tight construction. This was a challenge for the contractor. The final tests show that they managed to construct one of the air-tightest buildings in Sweden and that the calculated energy demand was about 44 kWh/m²/year. The client credited the committed site manager of the main contractor for the good technical quality.

5.4 The building in operation

The buildings are operated by a local division of the SFA operation department, while the user is the Swedish Defence. SFA is also responsible for the monitoring of the buildings. The buildings are fitted with many measuring points, on each flow, and for example on each radiator. The buildings are monitored in real time. No changes can be made to the operation of the building without the agreement of both partners (client and main contractor).

During the delivery the contractor made a review of the systems and their operation with the operational personal. An optimization of the systems was also made at the delivery. All checklists and other documents were transferred from the contractor to the operation. Special instructions were written for the operation. Routines and a handbook were produced.

Early indications of energy use were very good but after the first year of operation a higher energy use was detected. This was partly due to the energy used the first year to dry out the concrete construction – and considered as normal. However, there are also indications that the building does not function optimally⁸. The client and the contractor have gone through the contract and revised all contractual temperatures and flows and calibrated the building. After that a new monitoring period was initiated. It will end in April 2014.

Despite the lack of information, there are some indications that the building has not been used as planned. Some additional energy use included after the completion of the building (e.g. operational electricity for a newly installed solar heating system) and erroneous use of the building (weapon cleaning machine being left on for longer periods of use) has been deduced from the total use. However, according to the contractor, the users have kept doors open to individual rooms thus interrupting the automatic presence regulation for temperatures and ventilation and changing the energy balance of the building. This possible malfunction of the system was predicted by the consultant group in the preliminary design. It seemed obvious that the users would keep their rooms open onto common areas as a means to increase social interaction. A system with automatic door closers was ruled out due to costs and a note was made that users were supposed to close the doors. This incident could point at a problem and solutions which are not inscribed in the preliminary design, not documented and not transferred to actors in later stages of the process and maybe not even made known to the client.

6 DISCUSSION AND PRACTICAL IMPLICATIONS

This paper raised two questions:

- 1/ Did energy and sustainability objectives modify the relationships between the actors of a building project?
- 2/ How successful is this move toward energy performance?

In France, architects are not engineers by training. Those with an engineering background represent the minority. Consequently, the move towards energy efficiency mainly benefited to design offices that are staffed with engineers specialised in thermal simulations. However, in public procurement, the architect is still at the head of the design team and in charge of coordinating the construction project. Thus, the power of the architect is still strong despite the increasing role of the design office.

⁸ At this point it is not clear why and due to the penalty mechanism, no detailed information can be given.

In the Swedish case, the architect did not have any specialist knowledge in low energy building (some architect consultancies have that competence in-house). As the energy programme was set before all other documents, the energy coordinator had the key role during the preliminary design and in directing the team of consultants although not officially being the main consultant. The architect was then given a sub-ordered role and in the D&B phase no architect was involved. The architect has a weakened role in the Swedish construction industry and this case might point to an evolution in which the strong energy focus leads to an even weaker role for architects. The weak role of the architect seems to be accentuated by the increasing use of D&B contracts. It is interesting to note the sub ordered role of the architect in the Swedish project despite that the public client, SFA has an explicit Governmental directive to work for achieving national objectives for architecture and design. SFA are satisfied with the result of the project and find no contradiction between architecture and low energy construction while the architect is disappointed with the final expression of the building.

In the French case, neither the operator, nor the users were involved at the design stage. The power appears to be still in the hand of the design and construction team while the performance of the buildings on the long run relies mainly on the competencies of the operator and the behaviour of the users.

In the Swedish case, it seems that the role of the contractor was reinforced since he has to monitor the energy performance during the five years following the inspection. Like in France, the behaviours of the users were not fully integrated at the design stage. However, the operator was more involved during design and build. As shown by figures 1 and 2, stages overlap in Sweden while stages are separated in France. In the French case, this inability to integrate the operator and the users upstream partly explains why the expected energy performance is not reached despite a building with good intrinsic performance (the airtightness is much higher than in most buildings because the actors modified their practices at the design and build phases). There was also a lack of commissioning. Most clients, such as the Ministry of Ecology, Housing and Transport, are not aware of the advantage of this systematic process assuring that a building performs in accordance with the design intent and the user's operational needs. Thus, they are not ready to pay for this activity.

Similarly in Sweden, the complexity of the projects and the inability of the actors to integrate the behaviour of the users at the design stage explain a higher energy use than expected. However, the performance-based contract provides strong incentives to find solutions in order to reach the energy target established at the design stage.

7 CONCLUSION

Both cases are examples of new national ambitions regarding energy performance. They also illustrate a shift of power within the project team. Architects are at the head of the design team in both cases. However, engineers specialised in energy performance become relatively more powerful with new objectives and regulations focusing on energy efficiency in buildings.

Despite progress in low energy design and airtightness of buildings, there is still a gap between theoretical and real energy performance. There are on-going investigations in different groups nationally looking into the calculation methods to try to understand these errors. This gap appeared to be due to the difficulties to integrate occupants' behaviour and the performance in use of equipment.

The cases could also be examples of a rebound effect where the user behaviour challenges the technical and theoretical energy performance. This could point to a risk in making a building into a one-issue task – to reach a good energy performance – and thus neglecting other functions of a building which in the end might contribute to the failure of the energy objectives.

One of the limits of the research is linked to the case study approach which has limited the analysis to two stories. Moreover, the feedback is still very short. One year of operation is too restricted to make definitive conclusions. Indeed, after delivery it usually takes the operator about two years to learn how to optimise the building according to the behaviour of the users. Similarly, users need time to take over their building interior. Thus, more research is necessary in this field. More data on building in operation also needs to be gathered.

ACKNOWLEDGEMENTS

We wish to thank DHUP (Délégation Habitat, Urbanisme et Paysage) and Carnot Institute who financed the study. We would like also to express our deep gratitude to the people who were interviewed and provided valuable information. However, the views expressed are those of the authors alone and should not be attributed to those interviewed or their institutions.

REFERENCES

- ADEME (2007), *Les chiffres clés du bâtiment*, Agence de l'Environnement et de la Maîtrise de l'Energie.
- BEHI (2013), *Construction des nouveaux sièges IGN – Météo France – Suivi d'exploitation*, 17 mai 2013.
- Bröchner, J., Josephson, P-E, Kadefors, A (2002) Swedish construction culture, management and collaborative quality practice, *Building Research & Information*. 30(6), 392-400.
- Commissariat Général au Développement Durable (CGDD) (2009) *Entreprises de construction: résultats de l'EAE 2007 (Construction Companies: Results of the 2007 annual enterprise survey)*, *Chiffres et Statistiques (Figures and Statistics)*, n°58.
- Eisenhardt K. M. (1989), Building theories from case study research, *Academy of Management Review*, vol. 14, n°4, 532 – 550.
- Gluch, P, Gustavsson, M, Thuvander L and H Baumann (2013) Charting corporate greening: environmental management trends in Sweden. *Building Research & Information*,
- Grange, K (2010) Den svenska arkitekten – fast i ett historiskt etablerat styrkeförhållande. In Eds Graninger G and Knuthammar, C, *Makten över rummet – Tankar om den hållbara staden*, Stiftelsen Vadstena Forum för Samhällsbyggande: Vadstena
- Kadefors, A (2004) Trust in project relationships – inside the black box. *Int. Journal of Project Management*, 22(3), 175-182
- Nilsson, J-E (2008) *Upphandling, avtalsutformning och innovationer*. Forskningsrapport på uppdrag av konkurrensverket, Stockholm
- SCB, Swedish statistics (2010) Bostads- och byggnadsstatistisk årsbok, 2010
- Tellis W. (1997), Application of a case study methodology, *The Qualitative Report*, vol. 3, n°3, September, available at <http://www.nova.edu/ssss/QR/QR3-3/tellis2.html> accessed 10 April 2013.
- Winch, G (2000) Editorial: Construction business systems in the European Union. *Building Research & Information*, 28(2), 88-97.

2.3

SUSTAINABLE DEVELOPMENT: HIGH COSTS OFFSET BY EFFECTIVE PROJECT MANAGEMENT

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ABSTRACT

Sustainable development is retarded by cost implications. Clients are reluctant to pay the up-front costs relating to sustainable development. The need for sustainable buildings and affordable facilities is increasing with the rise in energy costs. The question is, how can clients be motivated to develop sustainable buildings and increase the trend to an environmentally friendly existence?

Purpose: The purpose of the paper is to identify cost saving measures through the effective application of the project management areas which are specifically directed at construction projects in order to generate funds required to offset the additional cost of sustainable development.

Approach: A literature review was conducted to identify the management areas relating to construction projects and the requirements for effective implementation. The questionnaire survey, based on the literature review was developed to identify the rate of importance and the extent of implementation of the management areas by professionals in the industry. In support of the quantitative data, interviews were conducted to gain the opinion of professionals relating to their views on cost saving implications in the management areas. The results were analysed and compared.

Results: It was found that there are cost saving alternatives identified in the management areas which may lead to cost savings on a project and ultimately counterbalance the additional upfront costs of sustainable development. Although clients are aware of the importance of sustainable development, in most cases they are not sufficiently informed of the potential cost savings, life cycle costs and the related benefits.

Practical Implications: The enhancement of sustainable development may result in a more effective facilities management system in the built environment.

Value: The identification of cost savings in project management presented to clients with whole lifecycle costs may lead to increased commitment to sustainable development and contribute to effective facilities management.

Keywords: Construction extension, PMBOK, Sustainable development, Cost savings

1 INTRODUCTION

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (International Institute for Sustainable Development (IISD), online: 2010).

Sustainability is considered a natural fit in facilities management and is supported by the “green” movement which relates to the preservation of the environment and the reduction of the negative effects humans have on the atmosphere and surroundings. A more effective Facilities Management process calls for the integration of sustainable development with emphasis on energy conservation and high performance buildings (International Facilities Management Association (IFMA, 2013). This may present a problem in South Africa where there is a slow trend toward sustainable development. This may be due to the onus of sustainability being on the owner/client. According to Mhlanga (2011), Geldenhuys of Abacus divisions, a property company with a strong portfolio in Pretoria, is of the opinion that the “green” trend is on the increase however; the initial costs may in all probability inhibit the movement. Geldenhuys believes that the construction of or the upgrading of existing buildings is the way to go however; upfront costs continue to hinder the process.

Minimum requirements for sustainable construction are being set in South Africa. Mandatory requirements have been implemented by the Minister of Trade and Industry who has amended the National Building Regulations Act and Building Standards Act stipulating that new commercial and residential buildings will have to receive at least 50% of its hot water requirements from renewable energy such as solar water heating (Selected Energy, 2011). Sustainable development is progressing however; South Africa has a long way to go in meeting the ultimate objectives.

Most South Africans are aware of the importance of sustainability and “going green” however; performance against this measure suggests a lack of commitment. Secondary data indicates that 84% of respondents of a survey of 44 were in favour of paying more for a “green” building, of which 52% were willing to pay 10%, and 25%, 20% more of the cost (Jacobs, 2012). The main cause of resistance invariably rests on the cost implications when clients are faced with additional project costs. Limited knowledge relating to the advantages offered by a comparative life cycle costing analysis and the potential of cost savings through effective project management may be the cause of this resistance. The commitment of clients and professionals to a sustainable built environment is questioned,

PRINCE2 is a registered trade mark of the Office of Government Commerce in the United Kingdom and other countries and is extensively used as a leading method of project management. According to PRINCE2 (2009: 4) uniqueness exists in all projects in so far as similar projects may vary in terms of different teams, customers or location. The Project Management Institute (PMI) in the Project Management Body of Knowledge (PMBOK) (2008) and the Construction Extension to the Project PMBOK (2007) are used as guidelines for more effective project management. The PMI in the Construction Extension to the PMBOK (2007) is of the opinion that due to the unique nature of the construction industry, no project is the same as another. The PRINCE2’s (2009) approach places more emphasis on the principles of project management which provide a framework for good practice and themes for continuous evaluation. The Construction Extension to the PMBOK (2007) addresses life cycles and specific practices in the construction industry which serve as guidelines in the following management areas:

- Safety Management,
- Environment Management,
- Financial Management and
- Claims Management.

It was determined by means of interviews that the PMBOK is generally being used as a guideline for project management in the South African construction industry. The Construction Extension to the PMBOK (2007) and PRINCE2 (2009) were intended to enhance effective project management in the industry in order to produce quality end products. Quality being defined as completed within the time, cost and scope requirements of the project. However, contemporary project management now focuses on the importance of life cycle costing for economical and efficient whole project control, comparing initial investment options and identification of the least cost alternatives for a period of 20 years. (Uniformat II, n.d.). The presentation of a comparative whole lifecycle cost analysis highlighting the advantages of sustainable features and the implementation of effective project management, may encourage clients to support sustainable development for the preservation of the environment. The implementation of lifecycle costing in the building industry is questioned.

The question raised is, to what extent are professionals applying the management areas and relaying their significance to the client? A further question posed is, have professionals identified the potential of cost savings in effective project management and relayed these and the advantages of comparative whole life cycle costs to the client?

The purpose of the paper is to research the current situation relating to sustainable development in the South African construction industry and determine if costs saving opportunities relating to the Construction Extension management areas are being identified in order to generate available funds which will offset the cost implications of sustainable construction.

2 THE CONSTRUCTION EXTENSION KNOWLEDGE AREAS

The Construction Extension to the PMBOK (2007) management areas are generally not applied in the full range of projects and are more specifically used in construction projects. The construction extension is integrated with the PMBOK (2008) for effective and efficient project management. Risk management plays an important role in the management areas and cost savings may be identified by integration of these areas. The guidelines for the management area were identified to determine the requirements for effective project management (Con. Ext. PMBOK, 2007).

2.1 Safety management

Notwithstanding the human factor, legislation, non-compliance, penalties and accident related costs, the effective implementation of occupational health and safety is intended to result in the successful completion of a project within the project parameters of cost, time and quality (Smallwood, 2007). Sustainability and safety go hand in hand with a goal of conserving resources. Sustainability addresses the environment whereas safety management conserves human resources (Taubitz, 2010). According to Haupt (2002), health and safety compliance is somewhat lacking in the South African construction industry which may suggest that clients are not being informed of the advantages relating to compliance. However, it is the responsibility of the employer's agent to present a report on the cost implications relating to effective

regulatory implementation. Quantity surveyors can have a direct influence on health and safety by ensuring that adequate provision has been made for compliance. Clients may have a negative attitude towards health and safety (Bomel cited in Musonda, Haupt & Smallwood, 2009). The onus of compliance with the health and safety regulations has been transferred to all stakeholders; particularly the client and non-conformance may result in serious consequences for the perpetrators (Haupt, 2002). As such, the client's responsibility is transferred to his/her agent, the professional (Kirkham, 19979).

Steinhofer (2006) is of the opinion that employers relate to health and safety as meeting the minimum requirements as stated in the regulations. If the culture of effective health and safety was entrenched in the values of construction stakeholders/companies, a commitment to a safer and more cost effective process may be created. Better pre-planning of a project may lead to the likelihood of less injuries and ultimately, higher profit margins. The Construction Extension to the PMBOK (2007) provides the following guidelines for effective safety management:

- A safety plan/policy
- Risk analysis
- Safety legislation
- Integration with the environment
- Integration with other management areas such as cost, quality, and the environment
- Safety assurance where plans are applied rigidly and
- Safety control on the contractor's performance.

Historical data confirms that investing in health and safety results in effective financial management in the project life cycle (Steinhofer, 2006). Fryer (19976) suggests that economic pressures to cut project times and cost militate against compliance and project managers need to make health and safety a high priority. This suggests that cutting costs in health and safety is not the answer to effective project management.

2.2 Environment management

Environment management addresses the impact the construction industry may have on the environment, the analysis thereof and the implementation of a project plan to mitigate the negative effects construction may have on the environment. The guidelines for effective environment management include the following:

- Statutory environmental requirements (legislation/regulations)
- Environmental assurance of implementation of plans
- Geographical environmental considerations
- A risk analysis on the effect on the environment and
- Implementation of environment control measures to make sure objectives are met (Con Ext. PMBOK (2007)).

Environment management involves the processes required to ensure that the project is executed in such a way as not to violate government regulations (Zack: 2004). The management of the environment is supported by the Environment Conservation Act 73 of 1989 and the relevant amendments. Environment management supports sustainable development which addresses human demands and the limitations which technology and society places on the environment. As such, economic growth is achieved without eroding the environment (Ofori,

1992). Besides cost, time and quality, the environment has been considered a fourth objective of project management (Ofori, 1992 cited in Stuckenbruk 1981, Bennett, 1983 and Walker 1990). However, sustainable development requires technical materials and techniques, at a price.

A great deal of research has been conducted on green construction materials and methods *inter alia*:

- solar geysers,
- variable refrigerant volume air conditioners,
- sanitary fittings,
- rain and groundwater harvesting
- energy efficient glass,
- motion sensors and
- LED lights which relate to long term cost savings (Mhlanga, 2012). These elements all have a price tag. As Geldenhuys states the problem, “who is going to fit the bill?” (E Prop Editor, 2011).

“A 15% increase in initial building costs can result in a 5% per year savings in running costs” (The Times, 2014). Due to lack of funding, sustainable development may be somewhat limited to the basic statutory requirements rather than apply the technical materials and techniques required for the construction of performance buildings. Cost savings may be identified in on-site reuse and reprocessing of construction, demolition and excavating materials and replacing costly materials with local substitutes (Wrap, 2013). However, recycling of waste may be limited to the construction site. Research by Coelho and Brito (2013: online) endorsed by the European Commission indicates that transport of waste costs cause the greatest environmental impact on projects. Quantity surveyors may encourage the use of recycled material from demolished buildings such as crushed concrete, and brick or steel beams in order to save money and protect the environment (The Times 100, 2014). This suggests that the negative effects construction has on the environment may be mitigated in a life cycle cost analysis; integrating environment and financial management.

2.3 Financial management

Financial management involves the identification, procurement and management of financial resources and the monitoring of cash flow for a project. Effective financial management is supported by the following processes and tools:

- Identification, allocation and monitoring of financial responsibilities
- Identification of source and availability of funds (banks)
- Contract requirements-in terms of payments
- Risk analysis e.g. sensitivity analysis
- Economic environment e.g. macro and micro economics
- Include the contractor’s plans and objectives
- Accounting systems and cash flow analysis
- Ethical practice
- Control of financial statements and adjustments (Con. Ext.PMBOK, 2007).

However, the duties of the quantity surveyor go beyond immediate cost planning, to whole lifecycle costs of a project (Kirkham, 2007). As such, the relationship between financial, safety and environment management may be a matter of weighing the cost versus the benefits relating to sustainable development. According to The Times 100 (2014), what is needed is to identify the balance between environmental saving and capital cost, referred to as the “environmental equation”. The Construction Extension to the PMBOK (2007) states that construction project management is limited to the construction and not to “operations” or facilities management. In the past more emphasis has been placed on the construction costs rather than the life cycle of the project. The International Organisation for Standardisation redefined whole life-cycle costs as *“a technique that enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational costs”* (Kirkham, 2007).

Emphasis is placed on the importance of the project life cycle in regard to defined decision points and deliverables. Deliverables may be extended to facilities management and demolition and as such, cost effective decisions are required to satisfy the needs of the client (Con. Ext. PMBOK, 2007). Life cycle costing has become an important factor in Facilities management. The IFMA (2013) supports the practice of sustainability and calls for professionals to become stewards of the built environment and advance sustainability throughout the building life cycle. Although clients may be aware of the extent of cost savings in relation to sustainable construction, their reluctance may need to be addressed. In view of the above, Quantity Surveyors may also adopt the role of steward in the building industry and promote sustainability for a friendlier environment. Comparative whole life cycle costs and cost savings in the supporting management areas may lead to more effective financial management in a project.

2.4 Claims management

Claims management is the process which addresses the mitigation of the negative effect claims have on a project by handling them quickly and effectively. A claim invariably stems from changes where extension of time is claimed or the quality of performance is being questioned by the client. This suggests that procurement measures should also be managed. Claims management is integrated with all the management areas in the PMBOK with emphasis on risk management. In the event of a dispute, parties may be referred to Alternate Dispute Resolution as a means of settling the claim. (Con. Ext. PMBOK, 2007). According to the Con. Ext. PMBOK (2007) the effective application of Claims management requires the following tools and processes:

- Prevent claims with a thorough risk analysis
- Identification and quantification of claims
- Unassisted dispute resolution between parties e.g. negotiation
- Settling differences by conciliation – 3rd party assists with negotiations
- Inform parties of the advantages of outcomes of the Four C’s *i.e.* consensus, control, continuity and confidentiality and
- Promote mediation adjudication and arbitration.

Loots, (1991) is of the opinion that differences can be settled by means of conciliation on site; the advantages enjoyed being satisfactory end results. However, a tendency exists in the South African construction industry for professionals to rely on their inherent skills to resolve a dispute (Dison, 2006).

The application of conciliation on site is questioned. Should professionals be aware of the skills required for effective conciliation, the expeditious resolution of disputes on site may in all probability lead to cost savings measures; by avoiding the costs related to Alternate Dispute Resolution ADR methods in the form of mediation, adjudication and arbitration. These functions are presented at an additional cost for the project.

2.5 Discussion

Risk management is repetitive in the Construction Extension management areas. Where safety and environment management is inclined to place risk on claims management, claims management places risk on financial management. Safety and environment management in the construction industry are closely related (Taubitz, 2010). Financial management is supported by safety and environment management relating to cost savings and are collectively supported by claims management in an event of a dispute.

In view of the above, effective project management calls for total commitment by the project manager in regard to the implementation of sustainable development. However, it is interesting to note that cost savings guidelines are not included in effective project management.

3 APPROACH

Interviews were conducted to determine the main source of reference for guidelines for effective project management in the South African construction industry. Having determined that the PMBOK is a preferred frame of reference to effective project management in the industry, a literature review was conducted on the four Construction Extension management areas in support of good practice and to determine the current situation in practice. The four management areas of the Construction extension were identified due to their specific relevance to the construction industry.

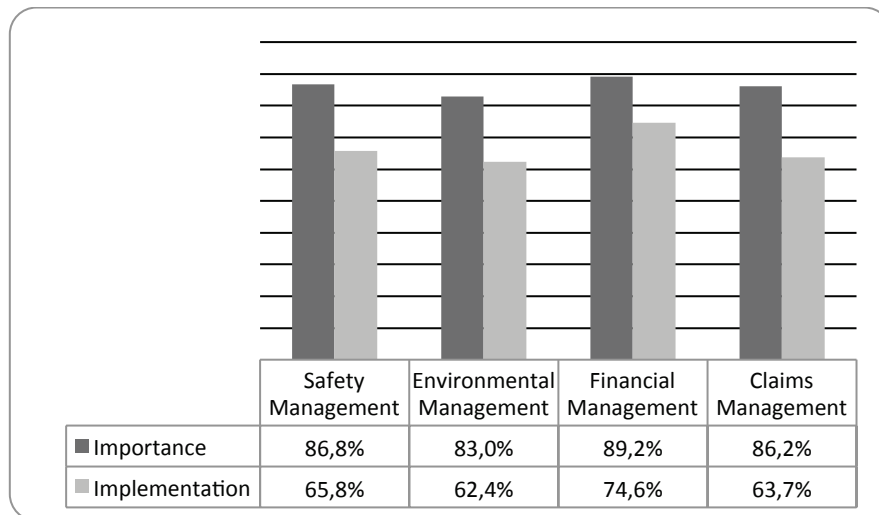
A mixed methods approach was adopted for the research applying both quantitative and qualitative measures in the form of questionnaires and interviews. The questionnaires were based on the findings of the literature review relating to good practice. One hundred questionnaires were distributed to practicing professionals who are currently active in the management of projects in the construction industry with a 41% response. This was to determine how the professionals rate the importance of the Construction Extension management areas and to which extent they are implemented in construction projects. The analysis was conducted on the Likert scale.

Having determined that the Construction Extension management areas are implemented adequately, a qualitative analysis was conducted in the form of interviews in order to determine the opinions of professionals in regard to cost saving methods relating to the practice of the four management areas. Twenty professionals who are active in the South African construction industry were interviewed in order to determine their approach to cost savings in the four management areas. The professionals were asked if it was possible to save costs and how they address these cost savings. The interviews were carried out to the point of saturation. The literature review, quantitative and qualitative data analysis were then compared by means of triangulation.

4 RESULTS

The findings of the literature review correlated with the qualitative data and to a large extent with the quantitative data. Figure 1 illustrates the findings of the quantitative data analysis in regard to what priority professionals rate the importance of the four additional construction extension knowledge areas, and to what extent they are implemented in the industry.

Figure 1: Project Management knowledge areas results



Respondents rated the four Construction Extension management areas as important as reflected in the literature review however; implementation is somewhat limited in terms of safety, environmental and claims management. The implementation of risk management which supports all these functions is also limited.

The implementation of safety management does not correlate with the findings of the qualitative data analysis. The qualitative data presented a largely uniform culture of investing in safety management and the majority of respondents were of the opinion that the more that is invested in safety, the higher the return. *“The more you spend on safety, the more you save.”* Others are of the opinion that compliance is sufficient and *“at least you can sleep at night”*. This suggests that professionals are aware of the importance of safety management and the need to invest in order to achieve success. As such, the reluctance tends to be with the client. Respondents working with State clients indicated that full safety compliance is met however; the problem lies with private clients who are not occupants of the buildings and will not benefit from the additional costs. As such, they seek short cuts resulting in non-compliance. Five respondents were of the opinion that to save money on safety management requires extensive planning and strategic management.

The environment management data analysis indicated that respondents were of the opinion that environment matters are important however; implementation is lacking as with safety management. The findings correlated with those of the qualitative analysis. The attitude toward the environment was somewhat reserved in so far as the respondents were of the opinion that environment management and sustainable development was an important consideration however *“it is not what the client wanted”*. Savings were sometimes calculated but the entire life cycle costing was not addressed. From an architectural perspective, the services of

an environmentalist is used however, it is noted that these are additional costs. An architect was of the opinion that cost saving factors *inter alia*

- the use of local materials in design;
- implosion methods and recycling;
- project management concerns such as transport and
- development which fits into its natural environment may be identified in order to highlight the direct cost savings.

In addition to this, factors such as market value should be used as motivators and carbon footprint tax may be an effective means of prioritising environmental management in the construction industry. Savings do not relate directly to immediate construction costs. This supports the slow trend of sustainable development identified in the literature review.

Respondents rated financial management importance and implementation as very high. The quantitative data analysis does not correlate with the qualitative data analysis. Although implementation is rated at 70%(which in all probability relates to direct construction costs), the processes and tools relating to sustainable development are seldom addressed as “*clients do not really ask for that. The whole life cycle is seldom presented to the client*”. This suggests that direct construction costs are managed successfully and the implementation of factors relating to sustainable development is lacking. As with safety management, State clients focus on direct construction costs and comply with minimum statutory requirements. Respondents confirmed that private clients comply with minimum standards and invest in sustainable development only when they reap the benefits.

The importance of claims management was rated high by the respondents and implementation is also lacking. The qualitative data analysis indicated that effective dispute resolution will minimize costs. Implementation correlates with the qualitative data in so far as respondents indicated that they “*rely on their inherent communication skills to resolve a dispute and are not really into the skills of conciliation*”. The minority were of the opinion that effective procurement and risk management are also required. State clients are referred to litigation.

4.1 Discussion

The South African construction industry has adopted a culture of meeting the basic statutory requirements for effective safety and environment management, which “*keeps them out of trouble*” and a reluctance to invest anything more than what is required or assumed necessary.

Implementation of the four management areas focuses on direct rather than whole project life-cycle costs. Having the greatest potential of contributing to sustainable development, not only from a construction point of view, but also from a macro point of view, it is surprising that environmental management was rated the lowest of the four management areas for implementation. Considerations *inter alia*:

- carbon footprint(tax related),
- utilisation of renewable sources of energy that dominate a specific context,
- localisation of materials to reduce cost and carbon footprint,
- sustainability of the urban environment to reduce long-term costs, all fall within the environmental management category.

Lack of implementation is an indicator of immediate cost savings as a priority over the savings throughout the building life-cycle.

Considerable research has been conducted on sustainable development which clients are exposed to. The advantages are advertised however, the question of costs halts the process. Professionals are inclined to “listen” to and accept the client’s point of view rather than inform them of potential benefits relating to cost savings. Should clients be better informed, they may fully appreciate the benefits of sustainable development. However, the findings suggest that in order to increase the trend toward sustainable development, professionals may need to accept responsibility of supporting sustainable development by encouraging the client with a comparative life cycle cost analysis and motivate this with cost savings through effective project management.

Although the Construction Extension to the PMBOK management areas are used as a guideline for effective project management, integration with risk management is most likely to lead to cost saving alternatives.

The effective application of safety, environment and claims management supports successful financial management. In conjunction with financial management, environmental management not only leads to cost savings but will expedite the trend toward sustainable development. Risk management forms a common element in all the management areas.

Claims management focuses on the ability to reduce the cost implications of the possible use of dispute resolution methods such as mediation, adjudication and arbitration. Litigation with regard to State clients may also be avoided by means of effective conciliation. By concentrating on conciliation skills in the claims management process, may lead to the resolution of disputes on site and indirect cost savings on the project. With increased conciliation skills and the effective implementation of risk assessment, claims management may lead to possible cost savings.

5 PRACTICAL IMPLICATIONS

The results of the research may motivate professionals in the industry in the practice of sustainable development. Clients may then be encouraged to invest in sustainable development; in turn contributing to effective facilities management and a sustainable environment.

The State may use the results of the research to identify the current situation in the industry when required to make decisions relating to a sustainable built environment.

6 CONCLUSION

The current situation in the South African construction industry calls for professionals to take the responsibility of motivating clients to develop sustainable buildings in order to increase the trend toward an environmentally friendly built environment.

It is concluded that the onus for an environmentally friendly construction industry rests on the professional, the agent of the client. Professionals may be required to gain insight into the presentation of comparative life cycle analyses and the identification of cost saving alternatives in order to support sustainable development.

7 RECOMMENDATIONS

Based on the research results, it is recommended that the Construction Extension to the PMBOK be used as a guideline to address specific practices required by construction projects and that the application is supported with additional cost saving measures to enhance sustainability.

It is further recommended that institutions address the need for whole project life-cycle costing, including facilities management and demolition in the form of Continuous Professional Development for professionals to update their knowledge and realise the importance of initiating sustainable practice in the construction industry.

REFERENCES

- Coelho, A and Brito, J (20013) "Recycling construction and demolition waste has substantial environmental benefits", available at: <http://ec.europa.eu/environment/integration/research/newsalert/pdf/329na1.pdf> (accessed 29 January 2014).
- Dison, L (2005), "An investigation into the mediation of disputes in the South African industry", *Journal of the South African institution of Civil Engineering*, 48 (1),p.23, September.
- E Prop Editor (2011), "Green buildings: great idea but somebody has to pay for it", available at: <http://www.eprop.co.za/index.php/news/item/13200-Green-buildings-great-idea-but-someone-has-to-pay-for-it> (accessed 5 February, 2013).
- Fryer, B. (1997), "*The Practice of Construction Management*". 3rd ed. Oxford: Blackwell Science.
- Haupt, T. (2002), "The state of construction safety and health education at higher education institutions in the Western Cape", SA "*Acta Structilia*" 9(2) 61-75.
- Institute for Sustainable Development, (2010), "Sustainable development from Bruntland to Rio", available at: http://www.un.org/wcm/webdav/site/climatechange/shared/gsp/docs/GSP1-6_Background%20on%20Sustainable%20Devt.pdf (accessed 15 January 2014).
- International Facility Management Association (IFMA), (2013), "Sustainability", available at: <http://www.ifma.org/know-base/browse/sustainability> (accessed 29 January 2014).
- Jacobs, E (2012), "The effect of green features on the perceived market value of quality residential properties in South Africa", In *Proceedings of the International Cost Engineering Council 8th ICEC World Congress*, Durban, edited by Pearl, R.G.and Verster, J.J.P., (ASAQS), 1–14.
- Kirkham, R (2007), "*Ferry and Brandon's Cost Planning of Buildings*". 8th ed. Oxford: Blackwell.
- Loots, P C. (1991), "Alternative methods of dispute resolution in the construction industry", "*SA Builder*", 8-13 May.
- Mhlanga, D. (2011), "R60 million green office building in Pretoria", available at: <http://www.property24.com/articles/r60m-green-office-building-in-pretoria/14303> (accessed 5 February, 2013].
- Musonda, I Haupt, TC and Smallwood, JJ (2009) Client attitude to health and safety - A report on contractor's perceptions. "*Acta Structilia*", 16(2), 69-85.

- Ofori, G (1992), "The environment: the fourth construction project objective?" *Construction Management and Economics*, **10**, 369–395.
- Turley, F. (2010), "The PRINCE2 Foundation Training Manual", Office of Government Commerce, United Kingdom.
- Project Management Institute. (2008), "*A guide to Project Management Body of Knowledge*", Pennsylvania: Project Management Institute.
- Project Management Institute. (2007), "*The Construction Extension to the Project Management Body of Knowledge Guide*", Pennsylvania: Project Management Institute.
- Selected Energy. (2011), "National Building Regulations and Building Standards Act. 2011", available at: <http://www.solahart.co.za/News/NationalBuildingRegulationsAct/tabid/16606/Default.aspx> (accessed 5 February 2013).
- Smallwood, J (2007), "Health and safety and the environment as project parameters", In: "CIB World Building Congress", 14-18 May 2007. Cape Town, available from: <http://www.irbdirekt.de/daten/iconda/CIB8751.pdf> (accessed 29 April 2011).
- Steinhofer, J (2006), "Cost savings through better safety", In: *Construction Business owner*, September, available from: <http://www.constructionbusinessowner.com/topics/safety/construction-safety/cost-savings-through-better-safety> (accessed 5 February, 2013).
- Taubitz, M (2010), "How safety fits with sustainability", available at: <http://ohsonline.com/Articles/2010/09/01/How-Safety-Fits-with-Sustainability.aspxf> (accessed 5 February, 2013).
- The times 100. (2014). "Sustainable development in the construction industry: A Gardiner & Theobald case study", available from: <http://businesscasestudies.co.uk/gardiner-theobald/sustainable-development-in-the-construction-industry/introduction.html#axzz2rhWJM1Id> (accessed 26 January 2014).
- Unifomat II (n.d.) "Improving building investment performance", available from: <http://unifomat.com/index.php/using-unifomat-ii/what-is-life-cycle-costing> (accessed 19 January 2014).
- Wrap. (2013). "Client cost saving guidance – incorporating reused and recycled materials", available at: <http://www.wrap.org.uk/content/client-cost-saving-guidance-incorporating-reused-and-recycled-materials> (accessed 29 January 2014).
- Zack, JG (2004), "Project Management in crisis: The role of the cost engineer and the quantity surveyor", In: "*IV World Congress of the International Cost Engineering Council (ICEC)*" 17-21 April 2004. Cape Town, South Africa. P. 1-7.

CHAPTER 3

WORKPLACE MANAGEMENT

3.1

Perceptions of Working Environment over CSR Policies

Saul Nurick, Muneeb Brey, Caitlin Soutar and Michael Watson

3.2

Measuring the Added Value of Workplace Change: Comparison between Theory and Practice

Chaiwat Riratanaphong and Theo J.M. van der Voordt

3.3

Managing Workplaces towards Sustainability

Heidi Rasila, Anne Sundqvist and Tuuli Jylhä

3.4

The Key Factors Behind Effective Use of University Laboratories

Jyrki Yläoutinen, Suvi Nenonen and Kalle Kähkönen

3.1

PERCEPTIONS OF WORKING ENVIRONMENT OVER CSR POLICIES

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ABSTRACT

Purpose: The purpose of this paper is to examine the perceptions of employees of four blue-chip property companies in South Africa. The main focus of the research is how employees view their company's Corporate Social Responsibility (CSR) and Corporate Environmental Responsibility (CER) policies in relation to their working environment with specific focus on Green Building Features and Initiatives (GBFIs).

Background: CSR is an explicit strategy by companies to engage with society by means of being socially and/or environmentally responsible. CER can be viewed as a type of CSR with specific focus on how a company engages with environmental challenges. Blue-chip companies have become increasingly aware of how their buildings impact the environment. Within a South African context, the increasing interest in green buildings has resulted in blue-chip companies attempting to incorporate environmental initiatives in their buildings that both improve the working environment and increase employee productivity.

Approach: Case study analysis was used as the over arching research method by examining four blue-chip companies. Semi-structured interviews were conducted with employees from each company. Employees also participated in an online survey, which supported each of the cases, however one of the cases did not permit their employees to be surveyed.

Results: The results indicated that GBFIs had a positive impact on employees in the workplace. Education about these benefits was found to be crucial in order for employees to fully realise the benefits of GBFIs. CSR adoption was found to be of varying importance between the companies reviewed and was dependent on the level of significance placed on CSR from senior management.

Practical Implications: The research could assist employers to better understand the long-term drivers that attract current and potential employees.

Research Limitations: The research was limited to blue-chip property companies that are located in Cape Town. Green building research is still in its infancy in South Africa, so the majority of the literature was sourced from Australasia, Europe and North America.

Keywords: Green Building Features and Initiatives (GBFIs), Corporate Environmental Responsibility (CER), Corporate Social Responsibility (CSR)

1 INTRODUCTION

1.1 BACKGROUND

The green building movement that has emerged is a result of a realisation that buildings contribute significantly to global carbon emissions (Dixon, 2009). It has been estimated that the building sector is responsible for more than a third of total carbon emissions (Bauer *et al.*, 2011) as well as 41% of all energy consumption in the U.S. (USGBC, 2012). The realisation of the impact that buildings have on the environment has led the global property sector to pursue methods of reducing their carbon footprint and to re-think the way it operates (Dixon, 2009).

As a result of the global shift in thinking about buildings and their environmental impact, more companies are implementing GBFIs in order to improve their environmental responsibility and to align themselves with current social expectations (Turner Construction Company, 2008).

1.2 Drivers for Green Building

The movement to construct green buildings is the fastest growing sector of the property industry with a total value of \$553 billion in 2009. The main driving factor behind this growth stems from occupiers wishing to improve on their green ratings and to enhance their CSR initiatives (Dixon, 2009). An important factor that is attracting the attention of investors and tenants is the opportunity to reduce costs of owning and occupying a building by implementing green initiatives. Green buildings are able to save on costs that regular buildings cannot. These include reductions in energy and water usage, less waste production, improved employee performance and lower operation and maintenance costs (Kats, 2003). There are significant drivers in the property sector that are making the adoption of GBFIs attractive to investors and occupiers. It is estimated that this growth is going to continue and that by 2015 up to 48% of non-residential new building stock will be classified as “green” with an approximate value of between \$120-145 billion (McGraw Hill Construction, 2010).

The South African commercial property market is starting to recognise the positive impact of GBFIs as opposed to a temporary phase for the built environment (Frost & Sullivan, 2010). The Green Building Council of South Africa (GBCSA) notes that the country is at a crossroads with regard to green buildings. Since the establishment of the GBCSA in 2007 and the initiation of the Green Star SA rating system in 2008, the mainstream commercial property sector has seen increasing momentum behind the construction of green-orientated buildings (GBCSA, 2012).

1.3 Focus of the Research

The main focus of the research is to examine how GBFIs are perceived by employees of blue-chip property companies in relation to their CSR statements. This was done by determining the main building attributes that contribute to employee awareness of GBFIs, as well as their awareness of lack of thereof pertaining to their employers CSR policy.

The research focused on four blue-chip property companies and to what level employees from each of these companies engaged with GBFIs and their employers CSR policy. This culminated in a cross-case analysis highlighting the similarities and differences of each of the cases.

2 GREEN BUILDINGS AND CSR/CER

2.1 Factors Promoting the Adoption of Green Buildings

In the last fifteen years there has been shift in attitude within the property and construction industry with regards to green buildings (Sayce, *et al.*, 2007). There are a number of factors responsible for driving the green building growth seen around the world. Bansal & Roth (2000) state that there are four main drivers of the green building movement. These are: (1) legislation, (2) stakeholder pressures, (3) economic opportunities and (4) ethical motives. One of the main drivers of the green building growth is that of tenant demand and changing tenant expectations that green buildings are becoming the norm (GBCA, 2008; Dixon, 2009). Bansal & Roth (2000) mention that stakeholders within the property section have played a pivotal role in the mainstream uptake of green building as result of expectations from customers and communities. Milne (2012) adds to this stating that increasing demand from market consumers, investors, shareholders, employees and communities had led to increased implementation of GBFIs.

2.2 Factors Limiting the Uptake of Green Buildings

The Green Building Council of Australia (GBCA, 2008) mentions that some of the potential hindrances placed on the adoption of green buildings can be related to poor knowledge about the principles of green building, a lack of value associated with long term benefits of green buildings, over-emphasis on the capital expenditure in the construction stages as well as a lack of consistency from government-support mechanisms. Milne (2012) states that a major factor preventing mainstream uptake of green buildings is the perception that green buildings require larger capital expenditure than conventional buildings; however is not necessarily always true and green buildings can often require similar capital expenditure to that of a conventional building (Kats, 2003). One of the most common barriers that is cited are that built environment professionals have a limited amount of expertise and experience regarding green building (Williams & Dair, 2007; Hoffman & Henn, 2008; Häkkinen & Belloni, 2011; GBCA, 2008). This problem is one that will slowly become less of an issue as green building practice becomes more common and initiatives used to promote green building become more prevalent (Williams & Dair, 2007).

2.3 GBFIs in the Workplace

Within the context of green building, and the drivers behind implementing GBFIs, is the concept that GBFIs have two positive effects (Heerwagen, 2000). It is common belief that green buildings increase productivity and health of those working in them, in comparison to buildings that do not contain GBFIs (Lee & Guerin, 2009). The factors of GBFIs that influence productivity include air quality and ventilation, lighting, and thermal control, of which per-

sonal control over these factors is key to increasing productivity (Heerwagen, 2000). With regards to health, the most important factors are access to daylight, and contact with or a view of nature, which affect psychological wellbeing, stress and emotions (Wise & Betch, 1999). The American Society of Interior Designers conducted a survey on people who were in a position to make business decisions. It was found that 97% of the respondents believed that improving the office design could increase employee productivity, and that the investment would be worth it if a correlation could be made between the cost and the productivity output (Wheeler, 1998).

Self-assessment studies of productivity have found strong relationships to air quality and thermal factors (Heerwagen, 2000). Occupants of buildings who had greater control over their environment perceived their comfort and productivity to be higher, as well as those occupants of buildings that are mixed mode, having both air conditioning and natural ventilation (Leaman, 1999). This is reiterated by a study done by Preller *et al.* (1990) in Europe where control over one's ventilation and temperature conditions led to fewer illness symptoms, increases in perceived productivity and less absenteeism. A study found that when the ventilation rate was increased, it led to increased productivity, decreased intensity of Sick Building Syndrome (SBS) symptoms and an improved perception of air quality, showing the benefits for human health (Wargocki, *et al.*, 2000). This study showed that there was an average increase in productivity of 17% overall for every two-fold increase in the ventilation rate.

Lighting is the other key factor when looking at how productivity is affected by buildings (Lee & Guerin, 2009). It contributes to both energy consumption and performance and this is why it is necessary to study the gains in productivity when introducing energy efficient lighting of a high quality. Specific lighting system is less important than the overall design in the space and the actual lighting conditions that are created by integrating certain components, such as the use of colours, furniture, windows, the use of antiglare screens and the positioning of the computers (Heerwagen, 2000). According to Lee & Guerin (2009), green design solutions may be chosen despite a lack of evidence. For example, when an imbalance between natural light and artificial light is evident, natural light is adopted without considering the quality of it. The study uncovered that the most frequent complaint regarding lighting was that there was a lack of it, and that in their personal workspaces they had a low level of luminance. Therefore the quality, quantity and the direction of the light was deemed to be an important criteria.

2.4 The Effects of GBFIs on Health

There are two main GBFIs that have an influence on health, namely: access to natural views, and access to daylight and sun penetration (Heerwagen, 2000). These factors have been found by Ulrich, *et al.* (1991) to be associated with increased job satisfaction, reduced stress, and more positive moods. Other studies, such as the one done by Wise & Betch (1999) have shown that by including the GBFIs such as daylighting, access to views of natural landscapes and the inclusion of vegetation inside buildings, the performance and health of occupants can improve. Access to natural views have an effect on health - according to studies done by Hartig *et al.* (1991) positive psychological effects are demonstrated when spending time in natural settings, whereas a feeling of enclosure was experienced when there was a lack of view (Nichols, 1977). Haber (1977) conducted a post-occupancy evaluation on the tenants of a high rise structure, and found the primary concerns to be a feeling of disconnection from outside, and a lack of greenery. When asked for suggestions for design improvement, the

most common responses were to increase natural light and include plants in the building (Haber, 1977).

2.5 Corporate Social Responsibility (CSR)

The prominence of CSR has only risen in the last thirty years as a critical discipline in corporate management; however, firms' contributing to the well-being of society is not an entirely new concept (Wan Jan, 2006). Different authors governed by different schools of thought generate varying explanations as to the exact nature of CSR (Moura-Leite & Padgett, 2011). Some argue that CSR in its nature is an excellent tool for a firm to market itself with, and thus should be led by marketers (Lantos, 2001) or it could simply be used to enhance a firm's brand (Lewis, 2003). Other participants argue that firm's should be socially responsible as it is their duty to behave in such a manner (Eichholtz *et al.*, 2009).

CSR is currently a fundamental element of the dialogue between companies and their stakeholders and it continues to attract attention at the top of the corporate agenda (Bhattacharya *et al.*, 2008). Hopkins (2007) indicates that CSR incorporates both economic and environmental responsibility and is inclusive of all stakeholders both outside and within the firm. Hopkins (2007) further states that the objective of CSR is to improve the standard of living whilst preserving the profitability of the corporation. Another viewpoint of CSR as an ethical stance is shared by Goyder (2003), whereby the concern is made that firms are implementing CSR initiatives merely to comply with expectations as opposed to doing so with the intention of enriching society. Goyder (2003) coined the term "compliance CSR" to describe firms using such practices, and stated that by implementing it would only inform stakeholders of what they want to hear in order to fit the firm into society's template. This form of CSR is the opposite of its purest form, which Goyder (2003) describes as "conviction CSR", whereby firms sincerely believe in a set of values and use conviction to act on them in order to positively benefit society. Firms which implement "conviction CSR" do so ensuring they will have positive impacts on the environment and society around them, all this should however be done in compliance with the law and within the realms of shareholder expectations (Wan Jan, 2006).

2.6 Corporate Environmental Responsibility (CER)

The underlying principle of CSR is that business and society are closely interwoven (Wood, 1991), and within this relationship the central issue has been the economic impact on a firm of its social policies. A separate relationship that business is evaluated on is that of the economic impacts of environmental performance, referred to as corporate environmental responsibility (CER) (Russo & Fouts, 1997). Corporations have had to incorporate environmental concerns into their business strategies and as such accept responsibility to minimise harm inflicted through business practices on the environment (Das, 2008). The shift in corporate mind set to prioritise the environment in their CSR policies was as a result of key drivers; Dummett (2006) outlines some drivers influencing this shift as being: government legislation or the threat thereof, cost savings, market advantage, protection or enhancement of corporate reputation, shareholder pressure and societal expectation.

The implementation of CER differs for various firms depending on which sector they operate in as well their business location (Das, 2008). Whilst many businesses considered CER policies only after government or public pressure (Russo & Fouts, 1997; Dummett, 2006), the precedent set as a result lends itself to the notion that businesses have sustainable develop-

ment in mind and consider their impact on the wider environment as well as on society in general.

3 RESEARCH METHOD

The chosen research method was case study analysis. Four blue-chip companies that have offices located in Cape Town were examined as the unit of analysis. Semi-structured interviews were conducted with two respondents from three of the companies, while one respondent was interviewed from the remaining company. The respondents were coded according to their corresponding case in order to maintain anonymity as shown in figure 3.1.

Figure 3.1: Case Study and Respondent Coding

Case Study	Respondent Code
Case Study 1 - Company 1	C1a, C1b
Case Study 2 - Company 2	C2a, C2b
Case Study 3 - Company 3	C3a, C3b
Case Study 4 - Company 4	C4

4 RESULTS

4.1 Case Study 1

Company 1 is a specialist retail property fund with specific focus on medium sized shopping centres in potential high-growth nodes. The company was started in 2007 and was listed on the Johannesburg Stock Exchange (JSE) in 2011. The company owns and manages a portfolio of properties throughout South Africa. Company 1 is located in a de-centralised business node in Cape Town. Company 1 rents A Grade office space from Company 3.

4.2 Case Study 2

Company 2 is a blue-chip life-assurance company that invests, develops and manages a large property portfolio in South Africa. Company 2 is a platinum founding member of the GBCSA and prides itself on being industry leaders in the incorporation of socially responsible investing (SRI) into their business strategy. CSR initiatives are promoted as being of importance to the properties owned and managed by the company. Company 2 flagship offices are located in Cape Town, which are situated between residential and industrial nodes.

4.3 Case Study 3

Company 3 is a REIT that is listed on the JSE. They own and manage properties in South Africa and Australia, providing more than 5.4 million square metres of space to the Retail, Office and Industrial sectors, employing over 450 people in South Africa. They are platinum founding members of the GBCSA and have recently issued a Green Addendum to all the leases for their tenants. They are also working closely with the GBCSA to create a rating tool for retrofitted buildings. Company 3 is located in the same business node as Company 1, in a mixed-use building, which they own and manage.

4.4 Case Study 4

Company 4 is the largest privately owned South African investment management company. Although not being a listed company compelled to report on a triple bottom line, Company 4 supports the principles set out by the Code for Responsible Investing in South Africa (CRI-SA) which includes having policies on the incorporation of sustainability considerations and

general ethical practice when conducting business. Company 4 at the time of interviewing was in the process of moving into its new Cape Town based headquarters (from a nearby but obsolete location), which was certified as South Africa's first six-star green rated office building by the GBCSA.

4.5 Tenant Awareness of GBFIs within the Office Environment

The building currently occupied by Company 1 was retrofitted by the landlords with a number of GBFIs. Both C1a and C1b were slightly aware of GBFIs in their building. There was a low level of awareness of efficient lighting systems and the water reticulation system in the toilets. C1a and C1b did mention that high quality of natural light was a positive attribute regarding their office space. It was noted that both C1a and C1b did not display significant awareness or knowledge of GBFIs both in general and in their office more specifically.

The building that Company 2 currently occupies is several decades old and has had periodical refurbishments over its life-cycle. The offices occupied by C2a and C2b were renovated in 2008. These refurbishments were predominantly of a cosmetic nature and had little to do with the implementation of any GBFIs. Overall both C2a and C2b were unaware of any GBFIs that were implemented in the building, except for a reduction in the size of the smoking area, but both respondents noted that this was probably due Company 2 having to comply with the latest smoking legislation.

C3a identified numerous GBFIs in their office space. The major features identified in their current office space were lighting and recycling, and it was acknowledged that in the company's new developments GBFIs such as solar panels, and catching as much light as possible were being introduced. The water component of GBFIs was also mentioned, but in the context of the shopping centres in the company's portfolio and not necessarily in the office space. With regards to lighting, according to C3a the company uses LED light bulbs, and sensors are used to turn the lights off when areas are not in use. C3a appreciated the recycling component of the GBFIs; there are bins in the kitchen for plastic and glass as well as shredder machines for paper that is no longer needed. A bulletin is sent out at the end of each year stating the amount of trees saved due to the shredding bins. The link between GBFIs and the health and productivity benefits were also recognised by C3a. 67% of the employees from Company 3 that participated in the online survey indicated that they had been adequately educated about the benefits of GBFIs.

Due to the fact that Company 4 was moving into a six-star green certified building their employees had been constantly informed of the benefits of GBFIs in an office environment. As a tenant occupying green office space, it is imperative that time was spent on lease negotiations to ensure that both parties were fully aware of the others requirements. A common reason for many tenants not choosing green office space is that due to the short length of their lease agreements, they do not see the financial benefits of occupying it. Company 4 spent nine months in lease negotiations with their landlord, which resulted in a favourable long-term lease allowing them to accrue the financial benefits, in the form of cost savings, as a result of occupying green space. Therefore, the length of lease negotiated often is the deciding factor when considering green office space as the premium paid is recouped over the long-term. Greening of the building was important to both parties albeit for marginally different reasons.

4.6 Current CSR Policies

Company 1 stated that due to the fact that the company was still in its infancy the implementation of CSR initiatives was a low priority. C1b noted that Company 1 is attempting to en-

gage with forms of social upliftment with regards to the communities that frequent their buildings. This is due to the fact that a large portion of their property portfolio comprises retail buildings located in rural areas. C1a and C1b made it clear that CSR played no significant role in determining the selection of new office premises for the company. Although CSR is seen as an important priority and has been addressed to a small extent in their property portfolio, it has not been factored in to the actual offices occupied by employees of the company.

Company 2 does not have a documented CSR policy however it focuses its CSR efforts on operations that encompass the properties within the portfolio. Management also use their discretion to select social projects that they deem fit for some form of social responsible investing. Company 2's rationale for implementing CSR initiatives is not financial gain, but instead for socially motivated reasons.

Company 3's CSR policy comprises two components; green and social. The green component comprises a green addendum that details how Company 3 will attempt to incorporate GBFIs at their own cost and the savings accrued will be split between Company 3 and the tenant. According to C3a, Company 3 engages with small service providers that they have assisted in establishing through training programmes to provide auxiliary support services for some of their buildings. This is mutually beneficial as it provides previously disadvantaged individuals with much needed skills that result in a steady income stream and Company 3 are employing service providers they that have already established a relationship with.

Due to the fact that Company 4 is not a listed company it is not legally required to have a stated CSR policy. Company 4 chooses to embrace its CSR initiatives directly through the education of its staff on the benefits of GBFIs. It has done this by providing its employees with a six-star green certified building, which will result in its employees being with a premium environment that is both beneficial to their health, but will also result in increased productivity and a decrease in staff turnover.

4.7 The Link Between Employee Perceptions of Workplace Environment and Company's CSR Policy

The information gathered from the interviews and surveys for Company 1 revealed that employees are aware that GBFIs will have positive benefits in the working environment. Adequate ventilation, lighting and access to daylight and views were perceived as being the most important. The majority of employees had received no notification or encouragement from their company regarding CSR policies and how employees could take part. There was a general lack of awareness about the role CSR plays in listed companies. C1a and C1b that suggested CSR was perceived as an administrative hurdle rather than a core aspect of the company's operations. The survey results emphasised and supported the interview findings. A substantial majority (82%) of survey respondents indicated that their personal working environment was more important to them than their employers CSR policy.

C2a and C2b stated that that personal comfort and convenience in an office space were of most importance and that it is unlikely that an employee would place more importance on their employer's CSR policy. Personal workplace comfort in terms of desks, chairs and general aesthetics of the office space were of more significance to both respondents. The impact their employer had on the environment and society was seen as something that would only be achieved over the long term and that of more concern was the environment in which employees occupy during their career at the company. The online survey indicated that three-quarters

(75%) of respondents from Company 2 would choose their personal working environment and comfort over how their company is perceived in the industry with regards to their reputation and CSR policy.

C3a stated that higher importance was placed on personal comfort than on the CSR of their employer. C3a also acknowledged that they wanted to be associated with a company that was an industry pioneer with regards to the implementation of GBFIs. C3a felt that there was a sense of employee pride being part of an organisation that was socially and environmentally conscious. The survey results were in favour of personal comfort over the CSR policy of their employer at 55%, but it is necessary to note that 45% ranked how their company is perceived in the industry with regards to their reputation and CSR policy as more important.

C4 indicated that most employees from Company 4 would rank their working environment as a more important factor than Company 4's CSR policy. It was noted that in their new six-star building Company 4 are supplying desks 30% smaller than their current ones, but are expecting higher productivity. Company 4 acknowledged that their employees are no different from any other company, and that working environment does play a role for their employees.

4.8 Cross-Case Analysis

Analyses of the four cases indicated similarities and differences amongst employee perceptions of GBFIs in their working environment in relation to their company's CSR policy.

Both Companies 1 and 2 displayed a lack of awareness of GBFIs, both in general and in their specific office environment. Company 1 has recently been retrofitted and does contain GBFIs, only small mention was made of the lighting and water features. Company 3 displayed adequate knowledge of GBFIs, both in their current building and in general. Knowledge of the link between GBFIs and health, productivity and well-being was also displayed. This is possibly due to the company's stance on educating their employees about the features in their building, 56% of the survey respondents indicated they had been adequately educated, in comparison to Company 1, where 82% of the respondents indicated that they had not been educated in this regard at all, and Company 2 where only 13% felt that they had been adequately educated. Company 4 revealed that a high level of awareness of GBFIs and their effects was evident. Knowledge of the GBCSA rating systems was also high, as the interviewee had visited Australia to learn about green building before embarking on the design of their future office space.

Company 1 treats CSR as more of an administrative hurdle rather than an intrinsic facet of the company's structure. Company 1 also approaches CSR from a social upliftment perspective rather than an environmental perspective. The employees from Company 2 revealed that education about the direct benefits to employees that GBFIs provide is necessary in order to be made fully conscious of how they are affected personally. The employees of Company 2 were more aware of CSR efforts implemented in their company but still placed more importance on their own comfort than on their employer's environmental impact. Perhaps the most revealing finding was that employees were unlikely to voluntarily become involved in CSR initiatives and that in order for them to do so they would need to receive a measurable and direct benefit. Company 3 revealed more balanced results regarding the importance employees place on workplace environment and their employer's CSR policy. However, employees still valued their own personal comfort and working environment over the CSR of their employer. A large minority (45%) of employees stated that they place more value on

their employer's CSR policy and reputation regarding environmental issues. This slightly more balanced spread is more than likely due to the fact that CSR initiatives are more actively promoted from senior management to their employees. Company made a concerted effort to educate their employees about the benefits of GBFIs in order to prepare them for the move into their new six-star building. Company 4's communicates the positive benefits that come as a result of implementing CSR into their corporate structure, however employees are still more likely to place more value on their personal comfort levels than on their employer's environmental impact.

A total of twenty-eight respondents participated in the online survey across Company 1,2 and 3. Company 4 declined to participate in the online survey, as they do not permit their employees to participate in external online surveys. The consolidated online survey results are shown in figure 4.1. The online survey results indicate that over 80% of respondents consider adequate ventilation, lighting and access to daylight of *importance* or *high importance*. Approximately 50% of respondents consider personal control (temperature) and access to views of nature to be of *importance* or *high importance*. These results indicate common physical workplace attributes that are considered to be important to employees regardless of their employer.

Figure 4.1: Consolidated Online Survey Results for Companies 1,2 and 3

	Not Important	Low Importance	Indifferent	Important	High Importance	Total
Adequate Ventilation	7%	4%	4%	18%	68%	100%
Lighting	4%	7%	7%	25%	57%	100%
Personal Control (Temperature)	7%	14%	25%	25%	29%	100%
Access to Daylight	4%	0%	11%	46%	39%	100%
Access to Views of Nature	11%	7%	36%	32%	14%	100%

5 PRACTICAL IMPLICATIONS

The findings of the research could be used to formulate CSR strategies that encompass the implementation of GBFIs. This could result in the alignment of employee satisfaction of their working environment, while simultaneously addressing the key points of a company's CER/CSR policy. Many companies use their CSR policy as a form of marketing to attract potential graduates, however it could be recommended that they shift their recruitment strategy to include awareness of the physical office environment so that potential employees will know what to expect if they were to be offered employment.

6 CONCLUSION

The research has identified that GBFIs have a considerable positive impact on employees in office environments. The main benefits include an increase in productivity, health and well-being. The research has also identified the GBFIs that are considered to be most important to employees; namely ventilation, lighting and sufficient access to daylight. It was also found that for these benefits to be sufficiently realised and appreciated, employees must be educated regarding their existence in the building and the benefits associated with them. It should be noted that due to a relatively small sample for the online survey the findings are considered to be indicative only.

Regardless of whether a company has a definitive CSR policy or not the overwhelming majority of employees placed more importance on their working environment than level of engagement their employer has with society and/or the environment. The extent to which CSR is implemented varies between companies as a result of their size, goals and corporate structure. Furthermore the adoption of and participation in CSR initiatives of employees varies due to the level of encouragement from senior management as well as the corporate identity. Greater participation in CER/CSR initiatives would be achieved through increased engagement and encouragement from senior management. This would result in employees placing a higher value on CSR in general and increase its significance within the blue-chip companies in South Africa.

REFERENCES

- Bansal, P. & Roth, K. (2000), Why Companies Go Green: A Model of Ecologic Responsiveness. *Academy of Management*, 43(4), pp. 717 - 736.
- Bauer, R., Eichholtz, P., Kok, N. & Quigley, J. (2011), How Green is Your Property Portfolio? The Global Real Estate Sustainability Benchmark. *Rotman International Journal of Pension Management*, 4(1), pp. 34-44.
- Bhattacharya, C., Korschun, D. & Sen, S. (2008), Strengthening stakeholder company relationships through mutually beneficial corporate social responsibility initiatives. *Journal of Business Ethics*, 85(2), pp. 257-272.
- Das, T. K. (2008), Corporate Environmental Responsibility, Sambalpur: SambalpurUniversity.
- Dixon, T. (2009), *Sustainability and corporate real estate*, London: RICS.
- Dummet, K. (2006), Drivers for corporate environmental responsibility. *Environment, development and sustainability*, Volume 8, pp. 375-389.
- Frost & Sullivan, (2010), *The South African Market for Green Buildings*, Cape Town: SouthAfrica.
- Eichholtz, P., Kok, N. & Quigley, J. (2009), *Why do companies rent green? Real property and corporate social responsibility*. [Online] Available at: <http://escholarship.org/uc/item/7xgl1t4ch> [Accessed 16 March 2013].
- Green Building Council of Australia (GBCA), (2008), *The Dollars and Sense of Green Building*, Sydney: Green Building Council of Australia.
- Green Building Council of South Africa (GBCSA), (2012), *Green Building Council of South Africa*. [Online] Available at: www.gbcsa.org.za [Accessed 13 March 2013].
- Goyder, M. (2003), *Redefining CSR: From the rhetoric of accountability to the reality of earning trust*. London: Tomorrow's Company.
- Haber, G. M. (1977), The impact of tall buildings on users and neighbours. In: D. Conway, ed. *Human response to tall building*. Stroudsburg, Pennsylvania: Hutchinson & Ross, Inc, pp. 45-57.
- Häkkinen, T. & Belloni, K. (2011), Barriers and drivers for sustainable building. *Building Research and Information*, 39(3), pp. 239-255.
- Hartig, T., Mang, M. & Evans, G. W. (1991), Restorative effects of natural environment experiences. *Energy Environ*, 23(1), pp. 3-26.
- Heerwagen, J. (2000), Green buildings, organizational success and occupant productivity. *Building Research & Information*, 28(5/6), pp. 353-367.
- Hoffman, A. & Henn, R. (2008), Overcoming the Social and Psychological Barriers to Green Building. *Organization and Environment*, 21(4), pp. 390-419.

- Hopkins, M. (2007), *Corporate Social Responsibility & International Development*. London: Earthscan.
- Kats, G. (2003), *Green Building Costs and Financial Benefits*, USA: Massachusetts Technology Collaborative.
- Lantos, G. (2001), The Boundaries of Strategic Corporate Social Responsibility. *Journal of Consumer Marketing*, 18(2), pp. 595-630.
- Leaman, A. (1999), UK study links productivity to ventilation systems. *HPAC Magazine*, 71(11), p. 14.
- Lee, Y. S. & Guerin, D. A. (2009), Indoor Environmental Quality Related to Occupant Satisfaction and Performance in LEED-certified Buildings. *Indoor and Built Environment*, 18(4), pp. 293-300.
- Lewis, S. (2003), Reputation and Corporate Responsibility. *Journal of Communication Management*, 7(4), pp. 356-394.
- McGraw Hill Construction, (2010), *Smart Market Report: Green Building Retrofit and Renovation*, Massachusetts: McGraw Hill Construction.
- Milne, N. (2012), *The Rands and Sense of Green Building*, Cape Town : GBCSA.
- Moura-Leite, R. & Padgett, R. (2011), Historical background of corporate social responsibility. *Social Responsibility Journal*, 7(4), pp. 528-539.
- Nichols, K. W. (1977), Urban office buildings: view variables. In: D. Conway, ed. *Human Response to tall buildings*. Stroudsburg, PA: Dowden, Hutchinson, & Ross, Inc, pp. 72- 80.
- Preller, L., Sweers, T., Brunekreef, B. & Bolej, J. (1990), Sick leave due to work related health complaints among office workers in the Netherlands. *Indoor Air '90*, Volume 1, pp. 227-230.
- Sayce, S., Ellison, L. & Parnell, P. (2007), Understanding investment drivers for UK sustainable property. *Building Research and Information*, 35(6), pp. 629-643.
- Russo, M. & Fouts, P. (1997), A resource-based perspective on corporate environmental performance and profitability. *The Academy of Management Journal*, 40(3), pp. 534-559.
- Turner Construction Company, (2008), *Green Building Market Barometer*, New York: Turner Construction Company.
- Ulrich, R. S., Simons, R F., Losito, B D., Fiorito, E., Miles, M A., Zelson, M. (1991), Stress Recovery During Exposure to Natural and Urban Environments. *Journal of Environmental Psychology*, Volume 11, pp. 201-230.
- United States Green Building Council (USGBC), (2012), *Green Building Facts*. [Online] Available at: <https://www.usgbc.org/ShowFile.aspx?DocumentID=18693> [Accessed 8 March 2013].
- Wan Jan, W. S. (2006), Defining corporate social responsibility. *Journal of Public affairs*, 6(3), pp. 176-184.
- Wargocki, P., Wyon, D.P., Sundell, J., Clausen, G., Fanger, P.O. (2000), The Effects of Outdoor Air Supply Rate in an Office on Perceived Air Quality, Sick Building Syndrome (SBS) Symptoms and Productivity. *Indoor Air*, Volume 10, pp. 222-236.
- Wheeler, G. (1998), *Presentation of ASID survey findings*. Cincinnati, Ohio, March 12-14, 1998.
- Williams, K. & Dair, C. (2007), What Is Stopping Sustainable Development In England? Barriers Experienced by Stakeholders in Delivering Sustainable Developments. *Sustainable Development*, Volume 15, pp. 135-147.
- Wise, J. & Betch, M. (1999), *The multiple benefits of energy efficiency*, Portland, Oregon: Unpublished paper.
- Wood, D. (1991), Corporate social performance revisited. *Academy of Management Review*, Volume 16, pp. 691-718.

3.2

MEASURING THE ADDED VALUE OF WORKPLACE CHANGE: COMPARISON BETWEEN THEORY AND PRACTICE

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ABSTRACT

Purpose: Worldwide organisations have introduced more flexibility in place, time and ways of working. In order to be able to define the added value of workplace change, a clear performance measurement system is needed to measure organisational performance in connection to real estate before and after the change. This paper compares various performance measurement systems from the literature with current performance management in practice in search of opportunities for improvement and prioritization.

Methodology: In addition to a review of literature, three case studies were conducted, two in Thailand and one in the Netherlands. Special attention is paid to appraisal of change by the end users i.e. employee satisfaction and perceived productivity support.

Findings: Many performance criteria and KPIs from literature are used in practice. However, apart from the Balanced Scorecard no other performance measurement system from literature is literally applied. Regarding most issues, none of the organisations conducted a sound comparison of the impact of their real estate on organisational performance before and after the change. In one case only both ex ante and ex post data were collected about the appraisal of change by the end users. Employees' appraisals showed to be linked to the location of the building, the office concept, the experience value of the exterior and interior design, and technical equipment.

Practical implications: The proposed performance measures can be used as a reference frame for value adding management of facilities. Based on the findings a step-by-step procedure has been developed to facilitate the selection of prioritized key performance indicators.

Research limitations: The number of cases is limited. Additional case studies in depth are needed to get a wider picture of practice. Besides, still much work has to be done to operationalize all performance criteria.

Originality/value: This research connects the worlds of performance measurement and added value of workplace change in two different contexts

Keywords: Workplace change, Performance measurement, Adding value management, Stakeholders

1 INTRODUCTION

Since the mid-nineties all over the world companies have implemented new ways of working supported by innovative workplace design (Becker, 1993; Aronoff and Kaplan, 1995; Worthington, 1997; Duffy and Powell, 1997; Van der Voordt, 2003; Becker, 2004). Drivers to change include both a lower need of floor space and cost reduction (focus on efficiency) and better collaboration, increased autonomy in how, where and when to work, improved productivity and creating an image of being progressive in order to attract and retain talented knowledge workers (focus on effectiveness) (Van der Voordt et al., 2012). In order to be able to define the added value of workplace change it has to be clear what added value actually means, which values are or should be involved, and how to measure the impact of workplace change on the organisation and its employees. This paper starts with current definitions of added value (section 2). Then it explores which performance criteria and indicators come to the fore in the literature (section 3) and which ones are being used in three workplace change practices (section 4). The comparison of possible and applied performance criteria aims to provide a reference frame for measuring the added value of workplace change. The paper ends with reflections on the findings (section 5) and conclusions and recommendations for further research and suggestions for improvement of measuring the added value of workplace change.

2 DEFINITIONS AND TYPES OF ADDED VALUE

Jensen et al. (2012) defined the added value of Facilities Management (FM) and Corporate Real Estate Management (CREM) as the trade-off between the benefits of FM and CREM interventions and the costs and risks to achieve these benefits. De Vries et al. (2008) defined the added value of corporate real estate as its contribution to organisational performance and the attainment of organisational goals from the perspective of various stakeholders. This definition links added value explicitly to better performance. Based on a review of the contributions by authors from different countries, different disciplines and different sectors (offices, universities, health care and industry), Jensen et al. (2012) detected six different types of added value:

- 1) Use value: quality in relation to the needs and preferences of the end users;
- 2) Customer value: trade-off between benefits and costs for the customers or consumers;
- 3) Economic, financial or exchange value: the economic trade-off between costs and benefits;
- 4) Social value: connecting people by supporting social interaction, identity and civic pride;
- 5) Environmental value: environmental impact of FM, Green FM;
- 6) Relationship value e.g. getting high-quality services or experiencing a special treatment.

Other researchers discuss different values as well, e.g. productivity, profitability and competitive advantage (De Vries et al., 2008) and sustainability (Den Heijer, 2011). The value types can be elaborated furthermore. For instance, competitive advantage might benefit from stimulating creativity and innovation and physical expressions of brand values (Khanna et al., 2013). Interviews with practitioners showed that in practice, too, various value types are included in FM and CREM decision making, dependent of the vision, mission and life cycle of the company and contextual factors such as the labour market and economics (Van der Voordt & Jensen, 2014). Organisations have to cope with both the pressure of cost reduction

and efficiency in order to succeed in a highly competitive business environment, and the need for quality, speed of delivery, flexibility, creativity, productivity and distinctiveness.

3. PERFORMANCE MEASUREMENT ACCORDING TO THE LITERATURE

3.1 Purpose of performance measurement

Performance measurement represents the yardsticks which gauge how well people have done and which motivate them to achieve higher targets (Zairi, 1994). It provides the inspiration to achieve superior levels of effectiveness and competitiveness. It focuses on the means and results or processes and outcomes (Zairi, 1994). Performance measurement can also be described as an important aid for making judgments and decisions. Performance measurement can help managers to answer five strategically important questions: 1) where have we been; 2) where are we now; 3) where do we want to go; 4) how are we going to get there; and 5) how will we know that we got there (Lebas, 1995). Sinclair and Zairi (1995) provided a list of seven topics to emphasize the importance and need for performance measurements. Performance measurement:

- enhances improvement
- can ensure that managers adopt a long-term perspective
- makes communication more precise ('say it in numbers')
- helps an organisation to allocate scarce resources to most attractive improvement activities
- is central to the operation of an effective and efficient planning, control, or evaluation system
- can affect the motivation of individuals by challenging but achievable targets and encourage right organisation behaviour
- can support management initiatives including Total Quality Management and managing change

Parker (2000) mentioned similar and additional reasons such as:

- identify success
- identify whether the organisation meets customer requirements
- understand their processes (to confirm what they know or to reveal what they do not know)
- identify where problems, bottlenecks and waste exists and where improvements are necessary
- ensure that decisions are based on facts, not supposition, emotion or intuition
- show if the improvements planned, actually happened

2.2 Performance measurement frameworks and indicators

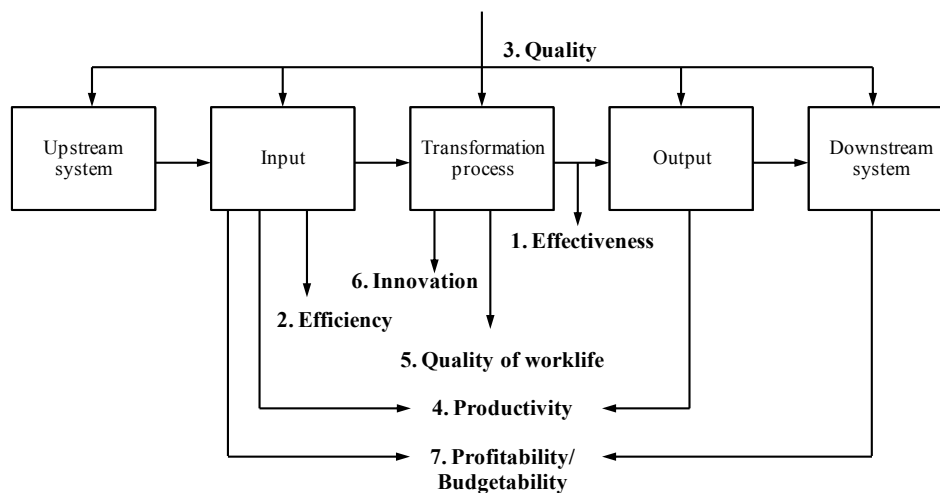
Many authors have reflected on performance measurement, performance areas and performance indicators and have tried to link performance to concepts such as quality, effectiveness and efficiency. This has resulted in a huge number of conceptual frameworks and measurement systems such as the performance measurement matrix of Keegan et al. (1989), the Balanced Scorecard (BSC) developed by Kaplan & Norton (1992), the Strategy Map developed by the same authors (Kaplan & Norton, 2004), the Performance Pyramid of Cross & Lynch (1992), the Performance Prism of Neely et al. (2001) and the Triple-P model developed by Tangen (2005). According to the well-known BSC organisational performance ought to be

evaluated from four perspectives: 1) Financial: profitability, revenue, sales growth; 2) Customer: customer retention, customer satisfaction, market research; 3) Internal business processes: processes to meet or exceed customer expectation; and 4) Learning and growth: how to grow and meet new challenges.

Sink and Tuttle (1989) identified seven performance criteria that are interrelated (Figure 1):

- *Effectiveness*: the degree to which an organization accomplishes what it set out to accomplish, usually expressed as a ratio of actual output to expected output;
- *Efficiency*: a ratio of resources expected to be consumed to resources actually consumed;
- *Quality*: the assurance of quality at five checkpoints: 1) upstream systems, 2) inputs, 3) transformation value adding process, 4) outputs, 5) downstream systems;
- *Productivity*: relationships between outputs and resources consumed;
- *Quality of work life*: feelings of workforces on key factors such as safety, compensation, pay;
- *Innovation*, a key element in sustaining and improving performance; and
- *Profitability*, representing the relationships between revenue and cost.

Figure 1: Interrelationship between seven performance criteria (Sink and Tuttle, 1989)



Bradley (2002) classified performance measures in six perspectives of business performance according to the Balanced ScoreCard (BSC) concept:

1. Stakeholder perception (customer perspective);
2. Financial health (financial perspective);
3. Organisational development (internal business process perspective);
4. Productivity (learning and growth perspective);
5. Environmental responsibility (internal business process perspective); and
6. Cost efficiency (financial perspective).

His six perspectives can be linked to the various types of added value that have been presented by various authors, see Table 1. As such the performance criteria can also be viewed as value dimensions. For instance performance measures related to productivity such as health,

safety and well-being can be considered as use value. Performance measures of environmental responsibility can be connected to environmental value.

Table 1: Comparison of performance criteria according to Bradley (2002) with various lists of added values

Bradley (2002)	Nourse and Roulac (1993)	De Jonge (1996)	Lindholm & Gibler (2005); Lindholm (2008)	Van Meel et al. (2010)	Den Heijer (2011)	Van der Zwart and Van der Voordt (2013)	Jensen et al. (2012)
1.Stakeholder perception (employee satisfaction)	Promoting HRM objectives	-	Increasing employee satisfaction	Attracting and retaining talented staff	Supporting user activities Increasing user satisfaction Improving quality of place	Increasing user satisfaction	Satisfaction
2.Financial health	Capturing real estate value creation of business	Increasing of value	Increasing the value of assets	-	Increasing real estate value	Improving finance position	-
3.Organisational development	Flexibility	Increasing of flexibility	Increasing flexibility	Increasing flexibility	Increasing flexibility	Improving flexibility	Adaptation
	Facilitating managerial process and knowledge work	Changing culture	-	Encouraging interaction Supporting cultural change	Supporting culture Stimulating collaboration	Improving culture	Culture
	Promoting marketing message Promoting sales & selling process	PR and marketing	Promoting marketing and sales	Expressing the brand	Supporting image	Supporting image	-
	Facilitating and controlling production, operation and, service delivery	Risk control	-	-	Controlling risk	Controlling risk	Reliability
	-	-	Increasing innovation	Stimulating creativity	Stimulating innovation	Increasing innovation	-
4.Productivity	-	Increasing productivity	Increasing productivity	Enhancing productivity	Supporting user activities	Improving productivity	Productivity
5.Environmental responsibility	-	-	-	Reducing environmental impact	Reducing the footprint	-	Environmental
6.Cost efficiency	Occupancy cost minimization	Cost reduction	Reducing costs	Reducing costs	Decreasing costs	Reducing costs	Cost

- = not mentioned

4 PERFORMANCE MEASUREMENT IN PRACTICE

4.1 Research methods

To improve our understanding of performance measurement regarding workplace change in different countries, two case studies were conducted, two in Thailand - Dhanarak Asset Development (DAD) and Philips Electronics Thailand (PTH) - and one in the Netherlands: Waterschap Rivierenland (WSRL). Criteria for case selection were actual implementation of workplace change, various business types (public and private sector), different cultural contexts, willingness-to-cooperate and availability of data. DAD and WSRL represent two public organisations whereas PTH is a private organisation. Data on performance measurement were collected from company reports and interviews with the case organisation's representatives, focusing on performance measurement frameworks and criteria and performance measures/KPIs. These empirical data have been compared with the criteria from the six perspectives mentioned by Bradley (2002). His perspectives cover many aspects of organizational performance and most areas on the added value of CREM/FM. Other comparisons have been conducted as well, e.g. with the seven performance measurement criteria mentioned by Sink & Tuttle (1996), but due to limited space we focus on the comparison with Bradley's perspectives.

The impact of workplace change on employees' appraisal was examined using the work environment diagnosis instrument (WODI). This questionnaire records employee satisfaction, perceived productivity support by the work environment, and prioritised aspects i.e. which aspects are perceived as most important by the employees (Maarleveld, et al., 2009). The findings of the WODI questionnaire were compared with the average percentages of satisfied employees on a number of issues in 96 cases in the Netherlands that were conducted by the Center for People and Buildings (CfPB) (Brunia, 2013), the so-called CfPB satisfaction indicator.

4.2 Research findings

a. Performance measurement

The case studies showed that apart from the Balanced Scorecard no other performance measurement system from literature is literally applied here. Regarding most issues, none of the organisations conducted a sound comparison of the impact of their real estate on organisational performance before and after the change. In only one case both ex ante and ex post data were collected about the appraisal of change by the end users. The three case studies also showed that performance measurement of an organisation is multi-dimensional and includes several performance criteria and performance measures beyond cost efficiency. All six perspectives presented by Bradley (2002) showed to have been applied in all three cases but with different interpretations and in different ways, see Table 2.

b. Employees' appraisal of workplace change

Table 2 presents the percentages of satisfied respondents in the three case studies and the average percentage of satisfied respondents in 96 Dutch cases (Brunia, 2013). The findings showed that all three cases have rather low satisfaction percentages on archive and storage facilities and privacy. The DAD employees are much less satisfied with most of the aspects compared with the Dutch employees. Several aspects of the PTH workplace have a much lower satisfaction percentage than the average of 96 Dutch cases, such as content and complexity of work (59% versus 80% in the average Dutch cases) and opportunities to communi-

cate (48% versus 71%). However, the satisfaction percentage of indoor climate is much higher in the PTH case (59%) in comparison to the Dutch cases (33%).

Table 2: CRE performance measures according to Bradley (2002) (left) and measures found in the case studies

1. Stakeholder perception	Bradley (2002)	DAD-case	PTH-case	WSRL-case
Employee satisfaction with work environment	Quality of indoor environment: lightning, air conditioning, temperature, noise level. Provision of safe environment Location success factors (access to employees, amount of local amenities) Ratio of office space to common areas Provision of amenities Amount of workplace reforms and space modifications	Employee satisfaction	Employee attitude survey (perceptions and attitudes related to employee satisfaction) Employee satisfaction survey conducted by Philips Real Estate	Employee satisfaction survey (WODI) User satisfaction survey (consumers)
Employee satisfaction with CRE services	Employee satisfaction with professional skills Employee satisfaction with information sharing	Employee satisfaction survey conducted by the author (WODI tool)	Employee satisfaction survey conducted by the author (WODI tool)	Employee satisfaction survey (WODI)
Customer satisfaction with facilities	Survey rating (e.g. customer/tenant survey of the facilities, building, property management and CRE services) Number of complaints Average call frequency and cost per square foot help desk Location success factors (proximity to transportation, access to customers, distance to other sites and businesses)	Satisfaction of the government complex building users	Rank in customer survey* Number of Complaints*	Customer satisfaction survey*
2. Financial health	Bradley (2002)	DAD	PTH	WSRL
Value of property, plant and equipment	Business return on real estate assets Real estate return on investment Real estate return on equity Sales or revenue per square foot (metre) Space (square feet or metres) per unit of revenue Return on property management	Income from commercially rented area Return on asset	NA	NA
3. Organisational development	Bradley (2002)	DAD	PTH	WSRL
Quality of facilities	Physical condition of facilities Suitability of premises and functional environment Number of building quality audits	Work done according to the development of building management and ICT standard	Risk management and business control (strategic, operational, compliance and financial risks)*	Risk Inventory and Evaluation (RI&E)
Accommodation usage	Square feet per employee Effective utilisation of space e.g. amount of teamwork space, vacancy rates, time wasted with interruptions due to open space layout	NA	NA	Square metre per desk (according to labour law)
CRE unit quality	Time used in project versus time budgeted for the project Money spent on project versus money budgeted on the project Amount of advice given to other business units	Delivering rentable area to other government agencies Percentage of allocating commercial area	% reduction in process cycle time* Number of engineering changes* Capacity utilization* Order response time* Process capability*	Design process descriptions and optimizing business processes*

Table 2 continued

4. Productivity	Bradley (2002)	DAD	PTH	WSRL
Employee productivity	Productivity (% of perceived productivity support from working environment) Absentee rates by buildings	Health & wellbeing in the workplace Productivity survey (WODI)	Health & wellbeing in the workplace through workplace innovation (WPI) Productivity survey (WODI)	Health & wellbeing through workplace design Productivity survey (WODI)
Strategic Involvement	CRE involved in corporate strategic planning CRE integrated with HR strategies CRE actively involved in firm-wide initiatives such as special asset use, consolidations, shared services	Master plan of the IT system Management of the information system IT solution in HRM	The implementation of the WPI Smart IT solutions for the Introduction of WPI	The implementation of the flex workplace
5. Environmental responsibility	Bradley (2002)	DAD	PTH	WSRL
Resource use	Energy consumption, Number of energy audits	Introduction of green building Construction materials and equipment meet local content	Green products* Energy efficiency improvement Collection and recycling of company's products* Amount of recycled materials in company's products*	Introduction of sustainable approach to the new building EU Energy label
Waste	Contaminated sites management, Amount of garbage	NA	NA	NA
6. Cost efficiency	Bradley (2002)	DAD	PTH	WSRL
Occupancy costs	Total occupancy cost per employee Occupancy cost as a % of total operating expense Occupancy cost as a % of operating revenue by building or business unit	Taxes (property and land)	Office rent (Baht/sq. m./month)**	Depreciation expense
Operating costs (building and FM)	Total operating expenditures versus budget including: general administration; capital expenditures; moves, adds, rearrangements; facility/properties services; other business services (mail, and copy centres, risk, and/or security) Facility management costs (environment, working conditions, quality)	Operating costs - Facility costs (buildings & equipment) - Overhead costs (employees and committee)* - Fees and services*	Utility (electricity & water) cost/unit Parking cost/month Overhead cost*	Operating costs - Salary costs* - Social charges* - Personnel costs of third party*

* does not directly relate to real estate; NA = not applied i.e. not measured or no data available, **40 Baht = 1 euro

Table 3: % satisfied respondents in three cases and average % in 96 Dutch cases (Brunia, 2013)

	DAD	PTH before change	PTH after change	WSR L	CfPB (2013)
Organisation	25	60	66	72	67
Content and complexity of work	32	64	59	83	80
Sharing own ideas about working environment	24	31	41	45	44
Accessibility of the building	37	55	62	72	78
Architecture and appearance of the building	59	45	45	91	55
Subdivision of the whole building	33	48	38	80	46
Number, diversity, and functionality of spaces	30	19	55	65	44
Adjacency and locality of the spaces	33	38	55	76	53

	DAD	PTH before change	PTH after change	WSR L	CfPB (2013)
Openness and transparency of environment	27	57	55	61	53
Functionality and comfort workspaces	37	52	62	70	56
Interior design appearance and ambience	29	43	62	60	50
Privacy	28	14	41	29	37
Opportunities to concentrate	23	7	52	33	39
Opportunities to communicate	51	43	48	75	71
Archive and storage facilities	25	24	34	42	36
ICT and ICT support facilities	21	52	48	47	53
Facilities and facilities management	23	52	55	67	53
Indoor climate	23	57	59	48	33
Lighting	40	64	69	48	58
Acoustics	21	48	52	48	44
Facilities for remote working	14	67	62	65	48

The WSRL case shows a much higher satisfaction percentage regarding architecture and the appearance of the building (91% versus 55% on average in 96 Dutch cases), subdivision of the whole building (80% versus 46%), number, diversity, and functionality of spaces (65% versus 44%), and adjacency and locality of the spaces (76% versus 53%).

Regarding perceived productivity support by the work environment, the percentage of satisfied respondents with perceived support of individual productivity in the DAD case (30%) is slightly lower than in on average in 96 Dutch cases (40%), whereas more PTH and WSRL employees are satisfied on this topic (55% and 45%). Regarding prioritized aspects, striking differences came to the fore as well, e.g. 39% of the DAD employees ranked adjacency and locality of the spaces in their top 3 of most prioritized aspects versus 17% in the PTH case and 5% in the WSRL case.

5 REFLECTION

Remarkably hardly any measurement framework that is presented in the literature is being applied in practice in its original form. Probably these frameworks are not known by practitioners or maybe perceived as too complex and not practically applicable. However, all performance criteria that were mentioned by Sink and Tuttle (1989) and Bradley (2002) showed up to be included in all three cases, be it with different interpretations and in different ways. The different applications might be due to different organisational contexts (i.e. business type, objectives, structure) and different external contexts. In addition to cost efficiency, in all three cases other dimensions of performance measurement are included in the performance measurement systems as well. Most performance criteria found in the case studies are measured by using various performance measures such as operational cash flow (efficiency), quality management (quality) and economic profits/earnings (profitability).

Various questions within the Work Environment Diagnosis Instrument (WODI) refer to opportunities to communicate and to concentrate and to sharing own ideas about the working environment. As such an assessment of employee satisfaction before and after workplace

change can be useful to evaluate support of knowledge sharing, which is of utmost importance in the current knowledge age. Data from WODI analyses could be compared with data from social network analysis or space syntax analysis (Kastelein, 2014) and lay-out metrics (Appel-Meulenbroek, 2014) to get a more complete picture.

The different percentages of satisfied employees and rankings of prioritized aspects per case can be used for benchmarking purposes. Organisations may compare their own percentages with an absolute standard (e.g. the aim to attain at least 80% satisfaction) or a relative standard (e.g. to perform better on satisfaction than the average of satisfied employees per aspect in other cases). However, better or worse performance compared to other cases is often difficult to explain, due to the impact of many influencing factors such as different organisational and employee characteristics, different national and organisational cultures, different workplace characteristics before and after the change, different work processes, different implementation processes and different internal and external conditions (Riratanaphong, 2014).

5 CONCLUSIONS AND PRACTICAL IMPLICATIONS

Efficient and effective management of corporate real estate and related facilities requires well considered decisions on how to align the facilities and services to the needs of the core business in order to add value to the organisation and to contribute to organisational performance. Evidence based decision making is only possible with valid and reliable data regarding the impact of real estate on organisational performance. The huge variety in performance measurement systems in the literature and the lack of data on the impact of facilities on organisational performance before and after workplace change shows that there is still a long way to go before a widely agreed, well defined, holistic and practically applicable performance measurement system is available to support decision makers and for benchmark purposes. Furthermore, further in-depth research is needed to explore explanations of cause-effect relationships between facilities and organisational performance before and after change and between various organisations.

In order to support organisations in how to select prioritized performance measures and KPIs out of a long list of possible KPIs, a step-by-step plan including six steps might be useful (Riratanaphong, 2014):

- 1) Inventory of KPIs that the organisation currently applies;
- 2) Clustering of all KPIs in two groups: organisational performance and corporate real estate performance.
- 3) Classification of all measures e.g. into the six categories of Bradley (2002).
- 4) Comparison of possible and currently applied measures and KPIs.
- 5) Reflection on similarities and dissimilarities in connection to the vision and mission of the organisation and its main objectives.
- 6) Prioritization of KPIs in connection to the main objectives and contextual variables such as economy and competitive advantage.

Questions that might be helpful to apply these steps are for instance: Which CRE characteristics align best to the mission and vision of the organisation and organisational objectives? Which CRE characteristics support the work processes optimally and which KPIs could be applied to measure these connections? Which CRE characteristics might influence productivity, profitability, competitive advantage and sustainability? Which areas are key? Similar

questions can be raised regarding other facilities and services. Further research could be helpful to further explore and test this step-by-step plan.

REFERENCES

- Appel-Meulenbroek, R. (2014), *How to measure added value of corporate real estate and building design*. Eindhoven: Technical University of Eindhoven.
- Aronoff, S. & Kaplan, A. (1995), *Total Workplace Performance. Rethinking the Office Environment*. WDL Publications, Ottawa.
- Becker, F. (2004), *Offices at Work. Uncommon Workspace Strategies that Add Value and Improve Performance*. Jossey-Bass, San Francisco, CA.
- Becker, F. (1993), *The Ecology of New Ways of Working: Non Territorial Office*. International Workplace Studies Program, Cornell University, Ithaca, NY.
- Bradley, S. (2002), "What's working? Briefing and evaluating workplace performance improvement", *Journal of Corporate Real Estate*, 4, 150-159.
- Brunia, S. (2013), *CjPB Indicator 2013*. Center for People and Buildings, Delft, Netherlands.
- Cross, K. F. & Lynch, R. L. 1992. For good measure. *CMA Magazine*, 66(3), 20-23
- De Jonge, H. (1996), "De toegevoegde waarde van concernhuisvesting". *NSC-conference, Amsterdam*. Amsterdam.
- De Vries, J. C., De Jonge, H. & Van Der Voordt, D. J. M. (2008), "Impact of real estate interventions on organisational performance". *Journal of Corporate Real Estate*, 10, 208-223.
- Den Heijer, A. (2011), *Managing the University Campus: Information to support real estate decisions*. Doctoral Dissertation, Delft University of Technology.
- Duffy, F. & Powell, K. (1997), *The New Office*. Conran Octopus, London.
- Jensen, P. A., Van Der Voordt, D. J. M. & Coenen, C. (2012), *The added value of facilities management: concepts, findings and perspectives*, Lyngby Denmark, Polyteknisk Forlag.
- Kaplan, R. S. & Norton, D. P. 2004. *Strategy maps: converting assets into tangible outcomes*, Harvard Business School Publishing. Massachusetts, USA.
- Kaplan, R. S. & Norton, D. P. (1992), "The balanced scorecard – measures that drive performance", *Harvard Business Review*, 70(1), 71-79
- Kastelein, J.P. (2014), *Space meets knowledge*. Breukelen: Nijenrode Business School.
- Keegan, D. P., Eiler, R. G. & Jones, C. P. (1989), "Are your performance measures obsolete?" *Management Accounting*, 70(12), 45-50.
- Khanna, C., Van der Voordt, D.J.M. & Koppels, P. (2013), "Real Estate mirrors Brands. A conceptual framework and practical applications". *Journal of Corporate Real Estate* Vol. 15 No. 3/4, 213-230.
- Lebas, M. J. (1995), "Performance measurement and performance management", *International Journal of Production Economics*, 41, 23-35.
- Lindholm, A.L. (2008), *Identifying and measuring the success of corporate real estate management*. Doctoral Dissertation, Helsinki University of Technology.
- Lindholm, A.L. & Gibler, K. M. (2005), "Measuring the Added Value of Corporate Real Estate Management: beyond cost minimization", *12th Annual European Real Estate Society Conference, Dublin, Ireland*.
- Maarleveld, M., Volker, L. & Van Der Voordt, D. J. M. (2009), "Measuring employee satisfaction in new offices - the WODI toolkit". *Journal of Facilities Management*, 7, 181-197.
- Neely, A., Adams, C. & Crowe, P. (2001), "The Performance Prism in Practice, Measuring Excellence", *The Journal of business performance management*, 5, 6-12.

- Nourse, H. & Roulac, S. (1993), "Linking Real Estate Decisions to Corporate Strategy", *Journal of Real Estate Research*, 8, 475-494.
- Parker, C. (2000), "Performance measurement", *Work study*, 49, 63-66.
- Riratanaphong, C. (2014), *Performance measurement of workplace change in two different cultural contexts*. Doctoral dissertation, Delft University of Technology.
- Sinclair, D. & Zairi, M. (1995), "Effective process management through performance management", *Business Process Re-engineering & Management Journal*, 1, 75-88.
- Sink, D. S. & Tuttle, T. C. (1989), *Planning and measurement of in your organisation of the future*, Industrial Engineering and Management Press, Norcross, USA.
- Tangen, S. (2005), "Demystifying Performance and Productivity". *International Journal of Productivity and Performance Management*, 54.
- Van Meel, J., Martens, Y. & Van Ree, H. J. (2010), *Planning office spaces: a practical guide for managers and designers*, London, Laurence King Publishing Ltd.
- Van der Voordt, D.J.M. (2003), *Costs and benefits of innovative workplace design*. Delft: Center for People and Buildings.
- Van der Voordt, T. & Jensen, P.A. (2014), "Adding value by FM: bridging the gap between theory and practice". *EFMC 2014*, Berlin, May 2014.
- Van der Voordt, T.J.M., Ikiz-Koppejan, Y.M.D. & Gosselink, A. (2012), An organization-centered Accommodation Choice Model. In: S.M. Mallory-Hill, W.P. E. Preiser & C. G. Watson (eds.), *Enhancing Building Performance*. West Sussex, UK: Wiley-Blackwell.
- Van der Zwart, J. & Van der Voordt, T. (2013), "Value adding management of hospital real estate. Balancing different stakeholders' perspectives". (E)Hospital Vol. 15, no. 3, 13, 15-17
- Worthington, J. (1997), *Reinventing the Workplace*, Butterworth-Heinemann, Oxford.
- Zairi, M. (1994), "Benchmarking: the best tool for measuring competitiveness", *Benchmarking for Quality Management & Technology*, 1, 11-24.

3.3

MANAGING WORKPLACES TOWARDS SUSTAINABILITY

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ABSTRACT

Purpose: The purpose of this paper is to introduce a framework for analysing the sustainability of workplace management. Further, the aim is to look at the Finnish governmental workplace concepts and look at the solutions that they utilize to become more sustainable.

Approach: The data gathering method for creating a framework for studying sustainability of workplace management is through workshops and interviews to validate the workshop findings. The data from governmental workplace concepts is analysed with a content analysis.

Results: The results suggest that there are five aspects of workplace sustainability. The workplace related sustainability is about 1) reducing the need to travel, 2) doing sustainable decisions about sourcing, 3) using the working environment in a sustainable way in day-to-day activities, 4) creating productive customer and work processes and minimizing the related real estate costs and 5) creating working environments that support the wellbeing of the end-users. The governmental concepts outline seven different solutions that may be used to build more sustainable solutions. These are: building technology, spatial solutions and interior design, aesthetics, ICT-solutions, rules of conduct, change management and economic steering.

Practical implications: The framework presented in this paper and the related workplace management solutions look at the sustainable use of the built environment from holistic perspectives. It also offers some tangible solutions that may be carried out in order to become more sustainable.

Research limitations: The work is still at initial phase and the material and data analysis are limited. Wider set of data and more scrutinized analysis would allow for deeper and more valid results.

Originality: This paper offers an insight to the sustainable actions of Finnish governmental workplaces and introduces a practically oriented framework for looking at the workplace sustainability in a holistic manner.

Keywords: Sustainability, Workplace management, Workplace concepts

1 INTRODUCTION

The sustainability of the built environment depends on the technical solutions but also the ways the built environment is used. This paper takes the sustainable use of the built environment as a starting point and looks at the ways workplace management could add value to sustainable actions in organizational context. In this paper, the definition of workplace management is paraphrased from a commonly used Finnish definition of corporate real estate management (KTI, 2012). According to this definition, workplace management may be defined as a part of facility management whose purpose is to integrate facility assets and usage into the corporation's key resources so that they add value to the productive work processes and workers.

There are many ways to assess the sustainability of built environment, such as LEED or BREAM and other international systems. From the workplace management perspective, these systems do not offer good enough guidance to how to manage the workplaces in a sustainable manner in daily activities. From this arose the need to create a framework for assessing the sustainability of workplace management not from the building perspective, but from the perspective of using the workplaces.

The aim of this paper is twofold. First, it aims at constructing a practically oriented framework for describing the sustainable elements of workplace management. The framework was initially created in workshops with actors involved in workplace management and then the framework was validated with interviews and small-scale workshops with sustainability experts and workplace managers. The framework includes five elements that are introduced in this paper. These are: supporting mobility, eco-efficient use, sourcing, wellbeing, and effectiveness.

Second aim of this paper is to utilize this framework to describe the sustainable solutions made in Finnish governmental workplace concepts. Some branches of Finnish governmental offices have been doing workplace concepts that outline the future intent of their workplaces and workplace management. These intents are described in the concept material of the branches in question. The second phase of this research was carried out by a content analysis of this material. There was material from five sectors of Finnish public administration.

This paper goes on to present the sustainable workplace management framework in the following section (*Section 2*) and the empirical study settings in *Section 3*. The *Section 4* of this paper outlines the practical solutions that are either effectively used or intended to be used in the future to enhance sustainability Finnish public administration workplaces.

2 APPROACH

2.1 Literature review

Sustainability is understood as an ability to maintain high quality of life and wellbeing to existing and future generations. (Blowfield & Murray, 2008; EU 10117/06). Traditionally sustainability was understood as only ecological construct, but today it is common to look at

the sustainability also from economic and social perspectives (Montiel, 2008). This approach is adopted also in the framework that is presented in this paper. Thus the sustainability is looked from social, economic and ecological perspectives.

The sustainability of different types of buildings has been studied a lot and from many perspectives. There are studies about sustainability of office buildings (e.g. Junnila, & Gyggemos, 2006), commercial buildings (Miller, & Buts, 2008), housing (Banfill, & Peacock, 2007; Priemus, 2005) and so on. Many of these studies concentrate on the building technology and ecological aspects of sustainability, such as emissions (e.g. Scheuer, & al. 2003). This is important as it has been estimated that a great deal of worldwide greenhouse gas emissions come from the buildings all over the world.

Money is also a central topic in the research on the sustainability of the built environment. Money is important as the changes to become more sustainable are many times costly and require investments that need to be justified to the actors in the real estate sector. Life-cycle costing has been one interesting approach (e.g. Aye, & al. 2000) to validate the benefits of investing in sustainability of the buildings. An important issue has been to show the real estate decision makers that in addition to ecological benefits, the sustainability related investments are also economically sound (e.g. Sayce, & al. 2007; Reed, & Wilkinson, 2005).

The interest has not been solely on the buildings and financing the sustainable solutions in new construction and renovations. The interest has also been on the human side of the matter. There is research about the investor and tenant perceptions of sustainable actions (e.g. Pivo, 2010). Also the organizational views about sustainability have been studied. For example Newell (2008) studied the strategic importance of sustainable premises to different organizations. Further, the sustainability has been studied from the point of views of facility management and facilities maintenance (e.g. Elmualin & al., 2009; 2010).

Looking inside the building, the workplace sustainability has gained much less interest than the building itself. Kato & his co-authors (2009) found out that a sustainable workplace is more precious to management compared to the workers. They also found that green workplace offer more psychological benefits than physical improvements. Another study on workplace sustainability by Smith and Pitt (2009) is focused on one minor aspect of sustainability, namely the plants in the workplace environment.

As the short literature review suggests the sustainability or workplace is a scarcely researched topic. The rest of this paper looks at the sustainability of built environment from the perspective of workplace management. The next section describes the process of creating sustainable workplace management framework.

2.2 The process of creating sustainable workplace management framework

The framework for sustainable workplace management created for the purposes of this paper was created in several phases. First, two workshops for sustainability experts (2) and workplace management experts (2) were carried out. The aim in the workshop was to find individual words that link the workplace management to sustainability. Second aim was to group these words so that the elements of workplace management sustainability would appear. This process generated 68 words and these words were grouped into 5 initial categories. The framework and the words behind the categories were then validated with 5 additional interviews and 1 workshop.

In the second phase of the analysis the Finnish nationwide governmental workplace concepts were analyzed. The Finnish nationwide governmental concepts have been created for 5 branches of administrations. These concepts outline the workplace management vision for the entire branch. Further, they lay the common rules for spatial solutions and ICT solutions when individual offices make workplace changes or go through a relocation process. These nationwide governmental workplace concepts were analyzed through a content analysis of the so called concept manuals. These manuals are written documents that outline the principles of workplace management and related spatial and ICT solutions. (Senate Properties, 2013.)

3 RESULTS

3.1 The process of creating sustainable workplace management framework

The sustainable workplace management framework consists of five elements. These elements are supporting mobility, sustainable use, sourcing, wellbeing, and effectiveness. These are defined as follow:

Sourcing. The sustainable sourcing in workplace management context includes the responsible acquisition of furniture, equipment, software and materials. When planning these acquisitions the possibilities to recycle and/or re-use should be considered. Also the expected life-span of the products should be used as selection criteria. The eco-certificates and other signs of using sustainable materials and production methods should be preferred. Sustainable production methods include, among others, using local suppliers and suppliers that utilize eco-friendly energy sources. Sustainable acquisitions do not take advantage of the black economy, trafficking of human beings, using child labor or other procedures that are socially irresponsible.

In Finnish governmental context the sourcing process is regulated and clearly instructed by the state. The rules are in the *State Sourcing Guidebook* (2010) and the guidebooks of individual branches of administration (for example Judicial administration, 25/2011). Further, the state has a sourcing strategy (2010). The strategy states that the sustainability in sourcing should be encouraged even though the regulations may be contrary to principles of sustainability. Thus, in the context of governmental offices the framework presented in this paper concentrated more on the planning phase of the sourcing, not the sourcing process.

Productivity. In a productive working environment it is possible to carry out both effective work processes and customer processes in a way that the resources are used as effectively as possible. A division may be made between spatial effectiveness and (work/customer) process effectiveness. The spatial effectiveness is typically measured as spatial efficiency, utilization rate and money spent on facilities. From the process viewpoint, the resources such as knowhow, space and technology, support the effective, efficient and productive processes.

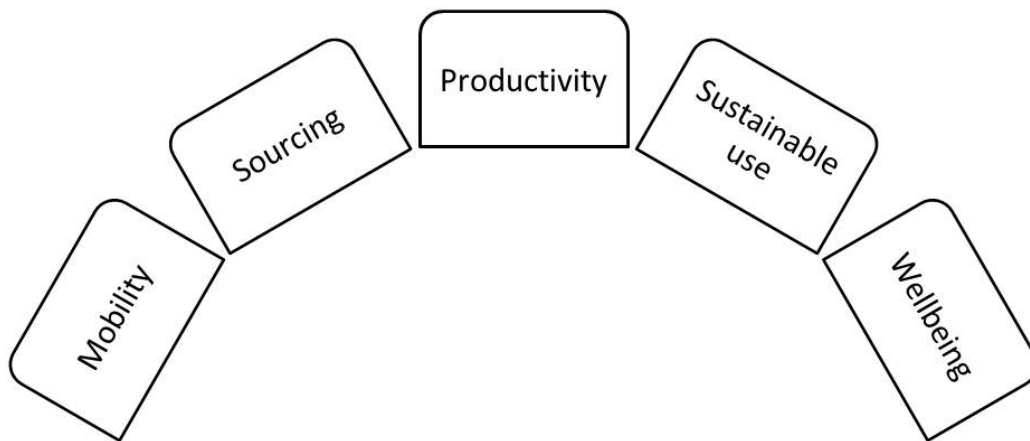
Sustainable use. In workplace management context the eco-efficient use of workplaces is limited to those issues that may be controlled – at least to some degree – by the users of the building. From this perspective, the eco-efficient working environment makes it possible for the individuals to adjust the energy use to their own needs. The sustainable workplace is designed in a way that allows for good quality maintenance operations.

The users are given information about how their actions affect the energy consumption and how they may control their environment. For example *Green Office* (www.greenoffice.com) policies are followed. The sustainable workplace allows the individuals to act in a sustainable manner and hinders unsustainable actions. For example the environment allows individuals to control the lightening but discourage them from excessive printing of unnecessary materials. At best, the sustainable workplace engages the end-users and the sustainable use spills over to the private lives of the employees.

Mobility. A sustainable working environment should support worker and customer processes in a way that reduces the need to move around in a way that is a burden to the environment. The working environment supports the sustainable ways of transportation and allows for carrying out the work and customer processes virtually where-ever and when-ever. The traditional way to do this is to allow individuals to telecommute and to enable the video-conferencing. Today, it is possible to multi-channel processes that allow the employees to carry out all the work or service related processes virtually.

Wellbeing. In a sustainable working environment both workers and customers feel well. At the basic level the environment must be healthy and safe. Further it should support things such as productive processes, work-life balance, feeling of privacy, good interpersonal relations, job satisfaction and feeling of being in control. These may be supported by providing different kinds of spaces for different kinds of situations and with technical solutions. The five aspects of sustainable workplace management are presented in *Figure 1*.

Figure 1: Elements of sustainable workplaces and workplace management



4.2 Sustainable solutions in governmental work environment concepts

The content analysis of the governmental workplace concept manuals revealed that four of the five elements of sustainability were met in the concepts. The sourcing was dealt with in none of the five concept manuals that were studied. Other four elements were covered in every concept (*Table 1*). The different elements of sustainability were met with seven different types of solutions. The seven types of solutions are introduced next.

Structural solutions are related to the building technology, building materials and building automation. These are typically solutions that are made during the construction of new work-

places or renovating existing ones. These solutions are difficult and often costly to change once they are finished. From the perspective of sustainable use the sustainable structural solutions allow to control the HVAC systems according to the user needs. This control of HVAC system may be either automatic (e.g. air quality sensors) or human-driven (e.g. ability to adjust the room temperature).

Table 1: The coverage of sustainability elements in the concept manuals. The box is grey when the element is covered in the concept manual.

	Sustainable use	Mobility	Sourcing	Wellbeing	Productivity
Concept A					
Concept B					
Concept C					
Concept D					
Concept E					

From productivity point of view structural solutions allow to make changes to the physical environment easily and effectively. Examples of such solutions include ceiling structures that allow for changing the location of walls easily. Further, from wellbeing point of view sustainable structural solutions increase accessibility, they are acoustically functional and safe. Finally, sustainable structural solutions make the mobility of employees and customers easy. Hands-on example of such solution is that the placing of sockets so that the employees and customers may charge their mobile devices where ever they happen to be.

Spatial solutions are decisions regarding the layout of the working environment. The furniture related choices are also included in this category. These decisions may be altered in middle or long term, but the change can be quite demanding and costly. Most of the sustainable solutions that came up in the content analysis of concept materials were related to spatial solutions. This is quite natural as the main point in concept creation process has been to set the common rules for spatial planning.

From the perspective of sustainable use the spatial solutions are related to things such as centralizing the printing and other office devices. These solutions discourage the employees from excessive printing and increase effectiveness of maintenance. The use of paper may be discouraged also by limiting the personal storage and advising the employees to give up their archives of books and papers. From the mobility perspective, the spatial solutions support the mobility through guest workstations and customer service areas that support mobile services. From the wellbeing point of view both customer wellbeing and employee wellbeing are important elements of sustainable working environments. In customer-employee interaction the concept materials point the need to have layouts and furniture that protect employees from potentially aggressive customers. The customer service desks should be arranged so that the customer can do all their processes at the same service desk. And the service desks should be arranged in a way that makes it easy for the customer to ask for help.

From the employee point of view a central part of the wellbeing is build-up from an ergonomic working environment. Tools for ergonomics include easy adjustability in desks and

chairs and ability to use these adjustments. On the other hand ergonomics may be improved by encouraging the employees to move around in the office during the day and to use different types of workstations. The importance of breaks is also acknowledged and concept material lays out different types of spaces for relaxation. Further, the privacy and noise conditions are important for the employee wellbeing. Solutions that enhance privacy and concentration include private enclosures, partitions and personal lockable storages.

Finally, from productivity perspective there are many solutions that add sustainability of the working environment. Increasing the utilization rate and decreasing the costs may be done by creating meeting rooms, social spaces and restaurants that may be utilized by all organizations that are tenants in the same building. The flexibility of the furniture is important so that the same spaces may be used in different ways and different kinds of actors.

Designing work-cafes, restaurants and meeting rooms so that they may be used as workstations when there is a peak in usage rate, allows for spatial efficiency through having less workstations than workers. Finally, using the traditionally non-usable spaces, such as basements and hallways as spaces for support function, increases the spatial efficiency.

Aesthetic solutions are decisions related to the visual appearance of the environment. All the concepts studied in this paper aimed at creating uniform visual solutions. Changing these solutions is typically made as part of spatial solutions. Improving the appearance of the premises may be done quite easily and thus it may be an effective way to make workplace improvements in a short or medium-timeframe.

The concept materials acknowledge the importance of the aesthetic solutions for the wellbeing of the workers. From this perspective the aim is to create a commonly shared appearance to the entire branch of administration and all sites. It is acknowledged that in addition to the pre-decided aesthetic elements, there should also be some elements that the employees may choose by themselves. This kind of elements may be about the colours, materials, motives and decorations such as plants or paintings. Interestingly the concept materials also acknowledge the importance of the aesthetic solutions on productivity. From this perspective the aim is to create an inspiring working environments and activating customer environments.

ICT solutions are decisions about the devices, networks and software that are used in the workplace environment. The employer may make these decisions on the behalf of the workers. From the customer perspective it is important to enable the use of customers own devices. Individual level changes may be done in a short term, but organizational level steps take a long time. From the solutions perspective standardized ICT solutions are easy to maintain. The good quality screens and possibility to use double-screens are a way to reduce paper because they encourage the employees to read from the screens instead of printing the papers and then reading them. The same applies to electronic achieving systems.

The ICT solutions are much about using different devices and software. From the customer perspective the sustainable way of using the ICT tools is about creating applications for the customers so that they may use their own devices either in a mobile way from where-ever they are or on-site. Also self-service is important in public administration of today. Thus the on-site self-service devices and software are important. For on-site use of own devices it is important to have wireless internet connections and it is also important that the customer devices are compatible with on-site systems and devices.

From the worker perspective the sustainable ICT allows the mobility of the workers. This includes the need to communicate with the colleagues (e.g. chats, videoconferencing) and to share data with them (data sharing software). It is also necessary to have electronic archiving accessible easily, always and anywhere. The ICT should be constructed so that also the individual remote work is possible easily and effectively.

Rules of conduct are common rules about using the premises and related virtual environment. These may be top-down rules – for example stating that some parts of the working environment are meant for silent work – or decided between the users of the environment. It is possible to change these rules in short term if needed and thus they are an effective way to manage the working environment.

In concept materials there are some solutions that enhance the sustainable use of the working environments. Such rules push for procedures that lead to paperless working environments (e.g. empty desk policies) and to increase recycling. From the wellbeing point of view the office policy directs the way the working environment is used. Examples of this are rules for long telephone calls or the way the personal aids are stored and utilized.

From the productivity point of view the rules for using meeting rooms are important. More coordinated meetings help in increasing the usage rate of the meeting rooms. If the employees commit to using the electronic reservation systems to booking the rooms and also when there is a need to change the booking, the space may be used more effectively. If it is commonly agreed that the material presented in the meeting is in electronic format, this rule of conduct also helps in reducing the amount of papers printed.

The rules of conducts are not meant just for the employees, as the employer may also commit to different rules of conduct. The concepts commit to following the laws and regulations. They are also committed to use experts, such as ergonomics experts or accessibility experts, in designing the working environments. Also the need to train the employees about the rules of conduct is acknowledged as the responsibility of the employer.

Change management is needed when the physical environment, virtual environment and/or the ways of working are changing. The concepts outline some change management related solutions that may be utilized in the relocation process. The relocation is a good point to turn to more sustainable ways of using the working environments. Educating employees in the relocation phase is thus important. The organizations may also force the change by, for example, giving the employees a limited number of moving boxes.

The change management is important in all big working environment changes, not just in relocation. The concepts acknowledge that it is important to legitimate the changes to the employees. Ways to do this include effective communications, training of the employees, participatory design practices and giving the employees the possibility to test the new solutions before they are implemented. The top management commitment helps and thus the change management may be more effective if the top management acts as test pilots.

Economical steering. Economic steering may be used as a way to direct the organizations and individuals towards more sustainable actions. From the organizational point of view the so called *Green Lease* agreements may push towards more sustainable use of working envi-

ronments. In these agreements the tenant organization gets monetary compensations if it acts in a sustainable manner.

Other solutions related to economic steering include measuring the spatial efficiency and utilization rates. If the spaces are not occupied in an effective manner, it is necessary to reconsider the solutions that are made. Economical steering includes also solutions that allow for sharing the spatial costs by the actual use and letting out space that is not used.

All these solutions were used to make the working environments more sustainable. Structural, spatial and ICT solutions were utilized most widely. Aesthetic solutions were used to increase both customer and worker wellbeing and productivity aspects of sustainability. Rules of conduct and change management were used to enhance sustainability from the perspectives of sustainable use and wellbeing. Finally, the solutions that were based on economical steering were meant to add the productivity aspect of sustainability. These findings are presented in *Table 2*.

Table 2: How the sustainable solutions cover different aspects of sustainable workplace managements

	Sustainable use	Mobility	Sourcing	Wellbeing	Productivity
Structural solutions					
Spatial solutions					
Aesthetic solutions					
ICT solutions					
Rules of conduct					
Change management					
Economic steering					

6 CONCLUSION AND DISCUSSION

Many times in built environment the focus is on increasing the ecological sustainability through technical solutions such as building materials and energy efficient HVAC systems. This paper looks at the sustainability of the built environment more holistically and looks at the ways the built environment is used. This is done from ecological, social and economic perspectives.

This wide view on sustainable use of built environment is looked from the perspective of workplace management. From the workplace management perspective this paper offers a holistic framework for looking at the potential solutions for improving the sustainability of workplace management and end-user actions and processes.

This paper outlined five aspects of sustainable workplace management. First, a sustainable workplace should be managed in a way that reduces unnecessary travelling and commuting. Second, it should enable the workers and customers to act in a sustainable manner. Third, a sustainable workplace utilizes the space in an effective manner while also supports productive processes. Fourth, a sustainable workplace makes all user-groups feel well and fifth, the sustainability is taken into account in sourcing and designing new environments.

A content analysis was carried out to see what solutions the Finnish nationwide governmental concepts suggest as tools for reaching these goals. These solutions included 1) structural solutions, 2) spatial solutions and interior design, 3) visual appearance, 4) ICT solutions, 5) rules of conduct, 6) change management and 7) economical steering.

The framework that is presented in this paper is an initial attempt to capture the sustainable use of workplaces and workplace management. The term *workplace management* is used here, to put the focus on the workers and work processes. The term is quite vague and there is no commonly shared definition of the term. The definition used in this paper does not tell much about the area that workplace management covers. Thus next step in the work will be to define in more detail the coverage of the term.

This paper has analyzed the Finnish governmental workplace concept manuals and the sustainable element in them. With a more thorough understanding of the term *workplace management* it will be possible to look also at those sustainability elements that do not exist in the concept manuals. This would widen the understanding of the sustainable workplace management.

REFERENCES

- Aye, L., Bamford, N., Charters, B. & Robinson, J. (2000) Environmentally Sustainable Development: A Life-Cycle Costing Approach for A Commercial Office Building in Melbourne, Australia, *Construction Management and Economics*, Vol. 18, Iss. 8, pp. 927-934.
- Banfill, P.F.G. & Peacock, A.D. (2007) Energy-Efficient New Housing - The UK Reaches for Sustainability, *Building Research & Information*, Vol. 35, Iss. 4, pp. 426-436.
- Eichholtz, P., Kok, N. & Quigley, J.M. (2010) Doing Well by Doing Good? Green Office Buildings. *American Economic Review* 100, pp. 2492-2509.
- Ellison, L. & Sayce, S. (2007) "Assessing sustainability in the existing commercial property stock: Establishing sustainability criteria relevant for the commercial property investment sector", *Property Management*, Vol. 25 Iss: 3, pp.287 – 304.
- Elmualim, A., Shockley, D., Valle, R., Lublow, G. & Shah, S. (2010) Barriers and Commitment of Facilities Management Profession to the Sustainability Agenda, *Building and Environment*, Vol. 45, Iss. 1, pp. 58-64.
- Elmualim, A., Czwakiel, A., Valle, R. & Ludlow, G. (2009) The Practice of Sustainable Facilities Management: Design Sentiments and the Knowledge Chasm, *Architectural Engineering and Design Management*, Vol. 5, Iss. 1-2, pp. 91-102.
- Hikari Kato, Linda Too, Ann Rask, (2009) "Occupier perceptions of green workplace environment: the Australian experience", *Journal of Corporate Real Estate*, Vol. 11 Iss: 3, pp.183 – 195.
- Junnila, S. & Guggemos, A. (2006) Life-Cycle Assessment of Office Buildings in Europe and the United States, *Journal of Infrastructure Systems*, Vol. 12, No. 1, pp. 10-17.

- Miller, E. & Buys, L. (2008) Retrofitting commercial office buildings for sustainability: tenants' perspectives, *Journal of Property Investment & Finance*, Vol. 26 Iss: 6, pp.552 – 561.
- Newell, G. (2008) "The strategic significance of environmental sustainability by Australian-listed property trusts", *Journal of Property Investment & Finance*, Vol. 26 Iss: 6, pp.522 – 540.
- Pivo, G. (2010) Owner-Tenant Engagement in Sustainable Property Investing, *The Journal of Sustainable Real Estate*, Vol. 2, No. 1, pp. 184-199.
- Priemus, H. (2005) How to Make Housing Sustainable? The Dutch Experience, *Environment and Planning B: Planning and Design* 2005, Vol. 32, pp. 5-19.
- Reed, R.G. & Wilkinson, S.J. (2005) "The increasing importance of sustainability for building ownership", *Journal of Corporate Real Estate*, Vol. 7 Iss: 4, pp.339 - 350
- Sayce, S., Ellison, L. & Parnell, P. (2007) Understanding Investment Drivers for UK Sustainable Property, *Building Research & Information*, Vol. 35, Iss. 6, pp. 629-643.
- Scheuer, C., Keoleian, G.A. & Reeppe, P. (2003) Life Cycle and Environmental Performance of a New University Building: Modeling Challenges and Design Implications, Vol. 35, Iss. 10, pp. 1049-1064.
- Smith, A. & Pitt, M. (2009) "Sustainable workplaces: improving staff health and well-being using plants", *Journal of Corporate Real Estate*, Vol. 11 Iss: 1, pp.52 – 63.

3.4

THE KEY FACTORS BEHIND EFFECTIVE USE OF UNIVERSITY LABORATORIES

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ABSTRACT

Purpose: The objective of the research presented in this paper is to identify the user-centered key factors of effective space use in university laboratories. The gained results are used to develop the university campus management to respond to collaborative space allocation processes as part of productive and sustainable campus development.

Background: In order to contribute to optimum space efficiency and effective use of laboratories campus management and end-users need to align the strategic, tactical and operational data and ways of thinking among diverse stakeholders.

Approach: Theoretically the paper builds on the demand and supply chains in the context of university laboratories: to be more specific in user-needs and requirements for campus management. The data is gathered from three different university campuses in connection with their laboratory projects. Different stakeholders (space users, university management as well as facilities management representatives) have been interviewed (n=56) in order to understand the different ways to determine the effective use of space.

Results: The results indicate that the information, which is used for the base of effective space use vary significantly. The diverse ways to measure and indicate the effective lab space resource are causing misfits and thresholds for aligning the use, maintenance and development of the spaces.

Practical implications: The results are used for producing efficient practices to establish space effectiveness in university laboratories when embarking on building projects as well when maintaining laboratories and managing the use of laboratory resources.

Research limitations: As the data is qualitative in nature and consisted of a limited data set collected in laboratory context the generalizability is limited.

Originality: The perspective of collaborative space allocation in the context of traditionally single-unit oriented space resource planning is a contribution to productive campus management.

Keywords: Campus management, Effectiveness, Space allocation, Laboratory spaces, User needs

1 INTRODUCTION

Successful space strategies resolve the needs of people in the business (demand) with the provision of appropriate workspace (the supply), (McGregor, 1999). He continues that the challenge in space management is the constant adjustment of the equation between the demand for, and supply of, space. Successful space planning resolves supply and demand based upon an understanding the present use of space and in doing so establishes a profile for the future use.

In the context of university the above mentioned business environment is much more complex system. With the special focus on university laboratories the challenges of successful space strategies are special. The purpose of laboratories in the universities is to serve as an instrument the scientific research process and learning. Effective use of laboratories requires many interrelated and simultaneous elements to enable safe and productive work. When designing laboratories it is crucial to identify the key factors that approach laboratory as a system taking into account design, usability and management drivers in order to achieve the preferred quality. Holland (1997) stated the factors that seem most likely to be associated with movement across levels include unit and campus leadership; financial resources including internal allocations, external funding, and incentives; internal and external expectations and demands (governing bodies, legislatures, community interest groups, local crises); community history and goals; and institutional motivations (learning, as a tool for community relations, and/or as student career development and exploration, for example).

This paper is presenting a qualitative research effort where the focus was to gather user-oriented data and “listen what the users think about the most important things when designing university laboratories.” The way of collecting the data was grounded to identify what the laboratory users “are really thinking” about effective use of laboratories. It was also valuable to identify the factors, which were not mentioned in user interviews and workshops but are traditionally in the administrative agenda of universities.

After introduction this paper discusses on the challenges of laboratories in campus management. The focus is on user needs and their significance in laboratory development. Chapter three describes the approach and methodology followed by results in Chapter four. The paper is finalized by discussing the practical applications and conclusions.

2 DEMAND AND SUPPLY OF UNIVERSITY LABORATORIES

The primary objective and demand in laboratory design is to provide a safe environment for laboratory personnel to conduct their work. A secondary objective is to allow for the maximum flexibility for safe research use. Harrison and Hutton (2013) have collected principles like creation of science experience for students, where the role of laboratories can be identi-

fied. They should provide possibilities to foster integration, communication and team working, accommodate change by flexibility, create sustainability and make science visible. Managing the balance between the growing demand for and the supply of research space is complicated. To address the issues of research space, universities have developed a variety of space management methods to fit their unique research missions, priorities, and operational culture.

According to Fink (2004) identifying research space needs and assigning research space requires a constant planning process. Allocating research space, unlike instructional classroom, class laboratory, and office space, increasingly involves the highest levels of university administration and governance, including deans, provosts and vice presidents. At the institutional management level, it is part of the larger picture of an institution's niche and priorities, part of its strategic planning and integral to campus finances. As campuses fulfill their research mission and enhance research productivity, each creates what it considers to be an effective strategy for funding, developing, allocating, and managing research space.

Fink (2004) continues that the assignment of research space is becoming more complex and dependent on high-level campus management as research becomes both multidisciplinary and interdisciplinary. New campus-level policies, organizational structures, and space assignment methods will need to emerge from the competitive research space environment as multidisciplinary research continues to grow. The trend may at some point result in the development of mega-units, spanning many departments, or the spinning off and forming of new, specialized units based on the collaboration of faculty across many disciplines.

These changes will require the development of new organizations and forms of governance for the management of research space. (Fink 2004.) Harrison and Hutton (2013) states that the key planning principle for future facilities is the anticipation of change. Fink (20014) state that universities want to provide faculty with the space resources to conduct research with the expectation the faculty will be creative and productive. Although the research space allocation and management process is complicated and universities each develop their own unique management models, in one way or another all address the following types of issues:

- Spatial arrangements
- Space assignment and policy
- Productivity
- Organizational structure
- Funding sources

During the last decades different theoretical models have been developed to optimise the efficiency of the space use. Such theories are e.g. the process architecture (Horgen et al. 1999), workplace planning (Robertson 1999, Bell and Joroff 2001), activity based workspace management (Pennanen 2004), mathematical utilization programming methods (Beyroyghy et al. 2009) and managing the university campus by corporate real estate management (CREM) framework (Heijer 2012). The productivity of space has also been studied by analysing the influence of space conditions for work performance (1999 CIBSE, 2006 Fraunhofer Lab 2020). Despite different approaches and practises there is still not very much information available of how to develop laboratories user-centered and productive way.

All in all the question is about the demand of users and supply of facilities and services – in the context of our paper especially university laboratories. Duffy (2000) reviewed the development of facilities management (FM) over the last 20 years having a parallel and similarly retrospective view is taken of developments in office design. The failure made by both actors has been an exaggerated notion of the importance of cost cutting leading to the predominance of supplying side values rather than serving the real interests of increasingly demanding views. He states also that if both facilities managers and designers (including architects) were to give proper attention, in a period of particularly rapid change, to user interests, then considerable and beneficial innovation would become possible (Duffy 2000).

3 APPROACH

3.1 Data Collection

The empirical data was collected during three laboratory renovation projects in three different university campuses of two Finnish universities within the period 2011-2013 (Table 1).

Table 1: Information about the case study organizations

Case	Campus 1	Campus 2	Campus 3
Project status	Renovation	Renovation	Renovation
Type of Lab	Biology	Chemistry	Pharmacy
Number of personnel	130-150	230	170-215
Sqm/person (future)	33-38	32	20-25
Estimated Proposition of total sqm (%)	-30%	-16-19%	-10%
Timeline for the data gathering (months)	6	12	8

The case projects can be characterised as workplace-pilot projects where the functionality of these premises was of prime interest and a leading design criteria. All the development projects were organized to support collaborative and open way to design the future lab solutions from the basis of user-centered goals and needs. The approach of work was a combination of qualitative research and user-centered design process called workplace management (WPM) - process. The real estate owners idea was to use the WPM-process in the learning and research environments for the first time. Reason for this was that the WPM projects had succeeded well in the office workplaces (2003-2011).

The data gathering methods were 9 individual interviews and 16 group interviews (both open and structured), 14 thematic workshops, www-based surveys (three inquiries), observation, info meetings for personnel and benchmarking (Table 2). 175 laboratory users answered the inquiries and 150 users took part in the facilitated co-creation workshops and events.

The case study laboratories are practising in natural sciences. The user in this study means the people who are working in the laboratories. The dean, professors, researchers, students, support service employees and other space users were interviewed in the similar way with the main theme of effective use of laboratories.

Table 2: The data gathering 2011-2013

Case	Campus 1 (2011-12)	Campus 2 (2012-13)	Campus 3 (2012-13)
Individual interviews	2	4	3
Group interviews	3	8	5
Thematic workshops	5	5	4
Personnel infos	2	2	2
CREM/FM inter-views	2	5	3
Individual interview (Deans)	-	2	1

3.2 Data analysis

The data was analysed by content analysis, which is a method used in this research with qualitative in an inductive way. When using content analysis, the aim was to build a model to describe the phenomenon in a conceptual form. The research followed three main phases: preparation, organizing and reporting. The concepts are derived from the data in inductive content analysis (Babbie 2010). To understand what issues the laboratory users identified critical for the effective use of labs the data was mapped in three categories: critical-important-not-in-mind (Figure 1). The criteria for clustering the data is following:

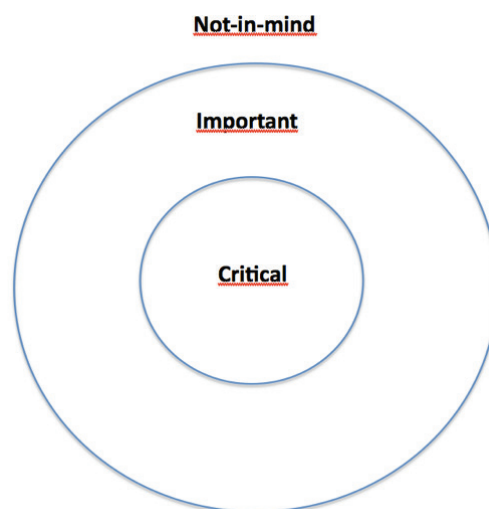
Critical includes data, which are essential for the daily functions and work performance in the laboratories.

Important is about topics that the users have to deal in their work but needs more effort and are not in the core of every day work focus.

Not-in-mind consist on issues, which are not known at all or things that are very complex, holistic and time consuming to take part as an actor.

When analysing the data there were differences based on the diversity of professional background, hierarchy and the role in the organization among interviewees.

Figure 1: Framework for data analysis



4 RESULTS

4.1 Effective Use of University Laboratories

University laboratories main function is to work as an instrument for scientific work processes and learning. The use of the laboratories effectively requires many interrelated factors. The key factors that are identified in this study were felt to be critical or important - if one part is missing, the whole system may collapse or the use of laboratories is not effective. Based on the research data **the key factors of effectiveness are** (not in priority order):

1. The ways of using the labs
2. Security
3. Spaces
4. Equipment
5. Tools
6. ICT-systems
7. Logistics
8. Sample management
9. Laboratory support services
10. Administrative services
11. Space Services (FM/CREM)
12. Other services (campus/business/WP)

The key factors can be clustered for three bigger groups: core work (1) + tools (2-7) + services (8-12). Part of the factors, like security, logistics and sample management, can be either part of core work or services depending on the policy and practises of the university.

4.1.1 *The ways of using the labs*

In this research context the ways of using labs does not mean to study the conceptual knowledge of science. Effective use of labs has seen here in relationship with work performance but not so much with work productivity. Work productivity has seen to be mainly “in the hands of the scientist.” The laboratory costs has seen as part of the total work costs and through that as part of the work productivity. Laboratory costs include infrastructure, spaces, equipment, tools and services.

The ways of working in laboratories has always been changing during decades. Many scientific innovations has been possible via new innovations in creating new tools and facilities (like the history and the working philosophy of Fraunhofer-institute in Europe). Excellent laboratories enable the work of science very concrete way and gives competitive advantage for the scientists. Vice versa not so well prepared lab facilities are reducing the ability to compete in the academic world and to contribute for the society. This gives the platform for strategic, tactical and operational discussion and decision making among university managers, laboratory users and stakeholders. The resource allocation decisions impacts straight to the ways of using labs and is a critical factor for effective use of laboratories.

4.1.2 *Security*

The realization of laboratory security comes from two main directions: from the use of the facilities and from the technical solutions of the labs and infrastructure. In the user side operates many different actors. Part of the users are very experienced - part of the users like students are in the early learning curve of safe laboratory use. Technical solutions like sensors

and zoning of different type of space areas helps executing the security but does not ensure the safety. Safety for people is seen as the first criteria including neighborhood of the laboratorio. The other objects for safety are information, innovations and material matters. In chemistry the chemical management is critical for dangerous items like drugs, toxic gases and radioactive materials. In the “dry labs” like mathematical analysis laboratories the information security is more dominant demand. The increased use of internet and working in international digital networks has set new challenges for the information security.

4.1.3 Spaces

The most occupied spaces in case study laboratories were the research laboratory and the office spaces. From the point of efficient space utilization the teachings laboratories were shown to be occupied very little per time. One of the case study faculties teaching lab was used 50 hours per year (for one course). At the same time the same user-organization was missing spaces for office work and teaching. In all three case study environments the teaching labs area were over sized for 200% or more. When starting to coordinate the curriculum from the point of laboratory use it was possible to save space and service resources and to deliver new spaces for the research work with minimum investments.

In synthesis laboratories the most common space related instrument is the fume hood. When analysing the case study laboratories it was shown that that the balance of the amount of fume hoods in the buildings was not working well. Synthesis laboratories had not enough fume hood capacity and the analytic laboratories were lacking space when having hoods that were not needed in their processes. The design solution to have the same amount of fume hoods through the building was not supporting the units work the best way. It was also shown that in the synthesis laboratories the average utilization rate of the fume hoods was under 10% per worktime. The idea to use shared hoods when possible would increase the efficient use of laboratories. Behind the hoods there is expensive technical infrastructure that is needed to ensure the safe indoor air for the users.

It seems possible that space utilization analysis, user-centered space design process and reallocation of spaces can enable rationalizing the use of university resources. Based on this study, there are some blank spots related to the laboratory workplace and facility management. The user-centered space allocation policies and practices vary significantly in different universities and faculties. The line between university space users space management and FM/CREM seems to be unclear. The real estate service providers needs more information of the key factors that are essential for the success in scientific laboratory work. From the users perspective there is need to develop more efficient, transparent and equitable ways to allocate and initialize laboratory resources.

4.1.4 Equipment

The professional research equipments are expensive. Some equipment are more expensive than the infrastructure (buildings etc) around equipment . The question of effective use of laboratories focuses very much for the possibilities to share the key resources like instruments. The international science community has traditions to share extremely expensive laboratories (like CERN, BSL-4-labs).

When looking for the next door and not so expensive resources in the case study faculties the willingness to share laboratories and services was shown less motivated. Part of the reasons for not sharing the tools and facilities was seen practical. The timing of the use was felt diffi-

cult to arrange. Also the condition of the equipments after some others using it was part of worries. The equipment management practises was mentioned as a critical requirement for the model of using shared equipment.

4.1.5 Tools

The tools in laboratory work are the ones that need maintenance every day. Such tools are the glass test-tubes and pipettes. It is very important for the scientific work that the tools are sterile when starting a research process. The question of who should do the dishes was asked in all three case laboratories. Sterilizing the glassware is time consuming work and it was asked that “should professor do the dishes?” To have the glass materials sterilized as a service is a question of resource allocation.

4.1.6 ICT-systems

The digitalization of scientific work is huge driver of change. Part of the “wet laboratory work” has already changed to work with digital equipment. For the analyzis work and the collaboration via information and communication technology is more crucial than ever.

4.1.7 Logistics

The material management for laboratory work is very important. The chain of the research materials from starting point of use and to change as a waste needs well organized systems and services. In bigger scale there are possibilities to optimise the flow and the use of chemicals, samples etc. as a shared service in the campus. One of the case campuses did not have a systematic and a holistic plan for logistics when the campus was designed and built.

4.1.8 Sample management

Sample management needs special storage solutions. The time window for sample management may be months or years. In case laboratories the responsibility of buying and maintaining the freezer based sample storages was not clear. The samples may be very valuable and unique as their nature. If the storages does not have sensors and reserve systems it is possible to ruin a long period research work when the storages stops working properly. There is need for collaboration between laboratory users and FM to agree about the risk management models in sample management and use.

4.1.9 Laboratory support services

Many of the laboratory equipment needs special knowledge to use. Instruments like NMR and mass spectrometry are special techniques of research and are used during the processes as one part of the research. To have the equipment is not enough - the knowledge and time resources to use the instruments is a critical factor for effective laboratory use. For this reason the idea of clustering the special equipment and knowledge into shared service centers in campuses seems rational.

4.1.10 Administrative services

For the effective ways of using laboratories the administrative services play important role. Based on the case study analysis the faculties could consider creating new administrative solutions to enable better use of lab resources. One part of the management is to know how many and what kind of people are working in the lab units. It seems that the spectrum of laboratory users is diverse and it may be difficult to know the right number of users in the faculties. In the pilot projects it was difficult to get valid user numbers to count the area per user as it really is. The difference between FM/administration and faculty units space user num-

bers was 25-35%. It was shown that in the faculties were more people working than what the FM thought.

For the space allocation the timing of using the spaces, location, size of the spaces and the equipments in the space are important. For the use of shared laboratory resources the location of laboratories can be local, regional or global. In the campus level the collaboration may be more difficult than in the global level even the physical distance is shorter.

4.1.11 Space Services (FM/CREM)

The FM services in the laboratory environments need special knowledge and practises. There is need for sharing information and experience between service people and companies. Because of the unique nature of different sciences it is not possible to find only one model to design and maintenance laboratories. Close collaboration with laboratory users is needed. In the case laboratories the main factors for effective lab use were the same. When supporting the research units in the faculties the details are critical. It is possible to learn and develop lab solutions with and for one scientific sector. The relevant approach to develop efficient FM services may be to create special areas of services like FM for radio-chemistry in one region (land, part of the world) or bigger organizational units (group of Universities, supplier alliances).

University laboratories are often situated in the campuses. The need for food, cafe and bar services were mentioned in the cases. Also a possibility to find services after working hours was asked. Many researches work during evenings and weekends. The case campuses does not serve users for 24/7.

4.2. Classifying the lab -data for three dimensions: Critical - Important - Not in Mind

When classifying the users data it was shown that from the laboratory users perspective the temporarily “here and now” factors were felt critical compared to the more long term factors that were important or not-in-mind (Figure 2).

Operational and personal matters seems to come more to users mind when asking about the effectiveness of the laboratory use. This kind of starting point is important to pay attention when analysing the user based data as a design brief for long term laboratory development. This kind of canvas may also affect for the amount of time that is needed in the design processes when laboratory projects have more time consuming goals on the agenda. The long term and more time demanding things were shown to be strategy, infrastructure, campus management, resource allocation, coordination of curriculum according to the efficient use of space and workplace policies.

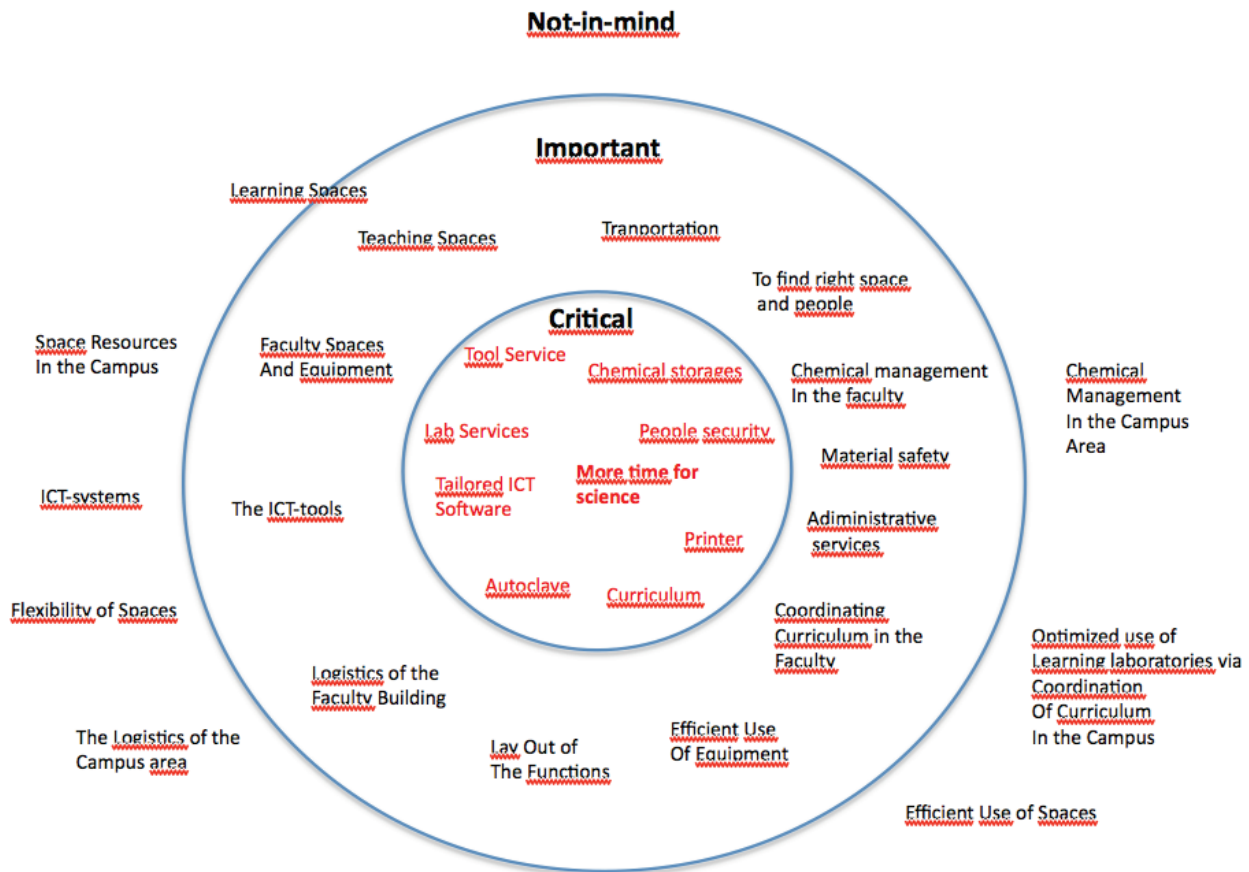
Most of the CREM/ICT-system -issues seems to be outside the core every day interest of the lab users. FM themes are closer the users thoughts and through that the willingness to develop next-to-me-fast issues may be bigger. For the laboratory users the “time is science” and may influence the users involvement and motivation to join in the campus development processes.

5 PRACTICAL IMPLICATIONS

For FM/CREM organizations the research may help to identify the laboratory user demands for effective use of laboratories when developing more productive ways to serve the laborato-

ry clients in universities. For University Administrations the results of the study can enable to develop new managerial ways to empower the scientific work in faculties.

Figure 2: Lab data in three dimensions: Critical – Important – Not-In-Mind



Learning to use laboratories more efficient way is challenge for the laboratory users. New models and pilot projects of space allocation and efficient use of laboratories may open way for next level practises of efficient space use in Universities. It is also possible to create mutual language among stakeholders for the laboratory projects of future.

6 CONCLUSION

The key factors of effective use of university laboratories are not very well understood and particularly research addressing user-centered perspective has been scarce. Understanding what the critical demands of effective university laboratory use are enables more efficient dialogue between laboratory users and FM suppliers. The benefits of better state-of-the-art understanding are applicable to laboratory users, university managers and service providers. It is also possible that more effective laboratories will deliver more advanced science for people and the world. That would be the highest win-win for all of us when heading towards shared resources and sustainable campus management.

REFERENCES

- Abras et al. (2004), *User-Centered Design* In Bainbridge, Encyclopedia of Human-Computer Interaction, Sage Publications, USA.
- Anon (2010) *Guideline for Physical Laboratory Space Allocation within the College of Medicine at the University of Vermont*, Effective July 1 (2010).
- Babbie, Earl R. (2010), *The Practice of Social Research* (12th ed.). Wadsworth: Cengage Learning.
- Beyroyghy et al. (2009), Towards Improving the Utilization of University Teaching Space, *The Journal of the Operational Research Society*, Vol. 60, No. 1, pp.130-143, Palgrave Macmillan Journals.
- Castor J. (2008), Lab Design and its Effect on Performance in Lab Work, *Lab2020 Research, Fraunhofer IAO*, Stuttgart.
- Duffy, F. (2000), Design and facilities management in a time of change", *Facilities*, Vol. 18 Iss: 10/11/12, pp.371 – 375.
- Fink, I. (2004). Research Space: Who Needs It, Who Gets It, Who Pays for It?. *Planning for Higher Education*. 33(1), pp. 5–17.
- Harrison, A. and Hutton, L. (2013), *Design and the Changing Educational Landscape: Space, Place and the Future of Learning*. Routledge: Glasgow.
- Holland, B. (1997). Analyzing Institutional Commitment to Service: A Model of Key Organizational Factors. *Michigan Journal of Community Service Learning*. Fall, pp. 30-41.
- Den Heijer, A. (2011), *Managing the University Campus*, Information to Support Real Estate Decisions. Delft, Netherlands: Eburon Academic Publishers
- Horgen et al. (1999), *Exellence by design: Transforming workplace and work practice*, John Wiley & Sons, Inc, Canada.
- Joroff, M. and Bell, M. (2001). *The Agile Workplace: Supporting People and their Work*. Boston, MA: Gartner.
- McGregor, W. and Shiem-Shin Then, D. (1999) *Facilities Management and the Business of Space*, London: Arnold.
- Oseland, N. (1999), Environmental factors affecting office worker performance: A review of evidence, *Technical Memoranda TM24:1999*, CIBSE.
- Pennanen, A. (2004), *Workplace Planning: Activity Based Workplace Definition as an Instrument for Workplace Management in Multi-User Organizations*, TUT, Tampere, Haahtela-kehitys Oy, Helsinki.
- Robertson, K.(1999), *Work Transformation: Planning and Implementing the New Workplace*. HNB Publishing, New York.

CHAPTER 4

CLIENTS AND USERS

4.1

Mapping Fields of Interest - A Systematic Literature Review on Public Clients in Construction

Pieter Eisma and Leentje Volker

4.2

Different Perspectives on Facilities Management to Incorporate in BIM

Mohammad Mayouf, David Boyd and Sharon Cox

4.3

The Shared Building Portfolio: An Exploration and a Typology

Rikke Brinkø, Juriaan van Meel and Susanne Balslev Nielsen

4.1

MAPPING FIELDS OF INTEREST - A SYSTEMATIC LITERATURE REVIEW ON PUBLIC CLIENTS IN CONSTRUCTION

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ABSTRACT

Purpose: To create an overview of scientific knowledge currently available on public clients in order to set up a research agenda for public commissioning in construction.

Background: Public clients are important actors and change agents in the construction industry. While sharing characteristics with private clients, they differ on terms of spending of public funds and by having to comply with European regulation. Operating in a public context requires transparency, objectivity and accountability of processes, procedures, projects and services.

Approach: We conducted a systematic literature review in Scopus and JSTOR. In total 171 articles were labelled relevant for the field of public commissioning. These articles were used to perform a quantitative study on the characteristics of the studies in the field. Additionally a network analysis of the topic was performed to identify the topics in the literature.

Results: Results suggest that most research focused on issues related to organising the project (procurement, contracting and management). Hardly any of the publications in construction management dealt with asset management of public clients, their internal organisation and their need to operate transparent, objectively and accountable.

Practical Implications: Two future research directions are identified to enhance the knowledge on public commissioning. Firstly, a focus on strategic asset management, the internal client organisation and the role in the public realm is needed. Secondly, the awareness of scientific knowledge in this field can be increased by translating the findings of previous work on procurement, contracting and management in practice.

Research limitations: The results are influenced by the choice of search engines (Scopus and JSTOR) and the exclusion of paper that were inaccessible, resulting in a small amount papers on specific subjects, such as purchasing, finance and legal issues.

Originality/value: Despite the importance of public clients in the construction chain, research on public commissioning is still in its infancy. The study provides directions for future research, complementing this interesting research field. A research agenda can stimulate oth-

er scholars in connecting adjacent research areas to improve the level of knowledge in this field and enhance the position of the public client in construction.

Keywords: Public sector, Construction clients, Literature review, Research agenda

1 INTRODUCTION

Clients are important actors in the construction industry. The literature on construction clients considers clients as the initiators of projects and those that contract other parties for the supply of construction goods or services (Boyd & Chinyio, 2008). Opposite to clients in mass-production sectors, clients in the construction industry play a large role in the creation of their facility or the facility they bear a responsibility for. They directly engage in the planning and construction and in this way they shape not only the ultimate product, but also the construction process (Hartmann, Reymen, & Van Oosterom, 2008).

Despite the importance of the clients, little research has been conducted. To address the lack of research into construction clients, Haugbølle and Boyd (2013) introduced a conceptual framework in the CIB W118 road map. The framework consists of the internal operation of the client, together with four key domains: 1. Business and Society where the client's purpose is given meaning; 2. Business and Users where the organisation of the achievement is enacted; 3. Buildings and Society where the client's building aspirations are regulated; and 4. the Construction Industry, which fulfils the building aspirations of the client. By putting the client's aim centrally in this framework, they create a different perspective from other work on construction clients (Haugbølle & Boyd, 2013).

The roadmap of CIB W118 features as a starting point for our research. We adopt the vision in the roadmap, but focus solely on clients in the public sector. While sharing many characteristics with private clients, they differ on terms of spending of public funds and having to comply with European regulation. Private clients do not have to comply with such a rigid externally enforced framework. Public clients operate in a public context. They therefore have to be transparent, objective and apply accountable procurement of projects and services (Morledge & Smith, 2013). Studies have shown that in a typical country, around 50% of the construction output is commissioned by a public client (state, municipality or other public body). Many of the private sector clients, (who are usually less experienced) tend to follow the model of the public clients (Winch, 2010). This indicates public sector clients are of great importance for the industry since they serve as an example. Furthermore, they are expected to act as one of the most important change agents in the construction industry. As such they also have a leading role in innovation and change.

Last year several major Dutch clients in construction decided to initiate a new Chair of Public Commissioning at Delft University of Technology. This requires setting up a research programme to increase the level of scientific knowledge in the domain and implement research results in practice. In order to identify the most important knowledge gaps, we conducted a systematic literature review. In this paper we present the research approach of this review and the results of this search. We identify related domains of commissioning in construction to support the scientific development of the discipline. Then we discuss the meaning of our findings in relation to the research agenda for our new chair in this challenging new field of science.

2 RESEARCH APPROACH

In this paper we address the following research questions: what are the main research themes in the scientific field of public commissioning? Which knowledge gaps can be identified?

To map the current knowledge on public commissioning, we conducted a literature review. According to Tranfield et al. (2003) this is an appropriate tool to map and assess the existing intellectual territory and develop the existing body of knowledge further. A systematic literature review is characterised by an accurate methodology section describing how the study was conducted (Crowther & Cook, 2007; Denyer & Neely, 2004). It can summarise large volumes of literature into manageable executive summaries (Crowther & Cook, 2007). This approach has in the past decades increasingly been applied by medical researchers (see for instance Checklists for review articles (Oxman, 1994). Recently the systematic literature review has been adopted in management studies (Tranfield et al., 2003). In this chapter we describe how we set up our literature review.

2.1 Query

As addressed in the introduction our aim is to map literature from a variety of academic domains (construction management, engineering, management sciences and purchasing) that relate to clients in construction. Therefore we did not limit our search to a specific set of journals or books, but focused on two main databases in these fields. First we used the search engine of Scopus to find papers with specific search terms in the title and/or abstract. Scopus contains around 50 million records about (amongst other) science, technology and social sciences⁹ and is considered one of the primary sources for applied science, including construction.

Inclusion criteria were:

1. Only articles, because of the guarantee of quality offered by peer review and the wide availability;
2. Written in English, because this is the standard scientific language;
3. Dated after 1st January 1990 (because the 90s marked a change in the opinion on the construction industry (see for instance the reports of Latham in 1994 (Constructing the Team) and the Egan Report Rethinking Construction in 1998);
4. Published or in press, because of the relevancy and timeliness;
5. Only content that can be accessed from the TU Delft Library, because of pragmatic reasons.

The query was developed in an iterative way. Our main focus was on public clients. It was therefore necessary both terms (“public” and “client”) appeared in our query. Because we found out some authors did not use these exact terms, we added synonyms such as government, (local) authority, parliament, commissioner and owner to emphasise the focus on the public sector client. Furthermore our aim was to find papers from different disciplines. Therefore we included “construction”, “infrastructure”, “real estate” and “architecture”. The last part of the query consists of tasks or interests of a client, such as “brief”, “asset management”, “partnering” and “tendering”. The final result can be found at the end of this paper (appendix 1).

Searching was performed in June and July 2013, and finalized on 18th July. Then we performed a similar search in JSTOR, because that database has a larger focus on management papers. The last search performed in JSTOR was on 23rd July 2013. Because the query from

⁹ <http://www.elsevier.com/online-tools/scopus>. Retrieved 17 September, 2013.

Scopus could not be used, we devised a different one. In JSTOR papers in which certain words are close together can be found. When the terms ‘client’ and ‘construction’ appear within 25 words from each other, the paper was included in our results. The same was done with the combinations ‘client’ and ‘infrastructure’, ‘client’ and ‘estate’ and ‘client’ and ‘architecture’. This query can be found in appendix 2.

The query in Scopus yielded 786 unique results, the one in JSTOR 181 unique results, so 967 in total. This set was subjected to further investigation to determine which papers suit the purpose of this review. For this we used exclusion criteria. The first was ‘availability of full text’. Using the licences and subscriptions of the TU Delft library on the 967 results from Scopus and JSTOR no full text could be found of 283 articles, leading to a set of 684 papers.

The second exclusion criterion was ‘focusing on construction/infrastructure’. Despite the careful composition of the query, a lot of papers appeared to focus on other domains than construction, such as legal advice and computing. Both authors read the abstracts of the papers independently and rated them on a scale from 1 to 3 on relevance for the field. Then we discussed for each paper the ratings. When our opinions differed, we discussed the reasoning until agreement was reached. 516 papers did not primarily focus on construction/infrastructure and were therefore excluded from further analysis.

We then discovered a difference between papers that considered clients as one of the many stakeholders in the construction process and papers that primarily focused on the interests of clients. We therefore divided the remaining set of 171 papers into two categories:

- *Category 1: first tier papers*

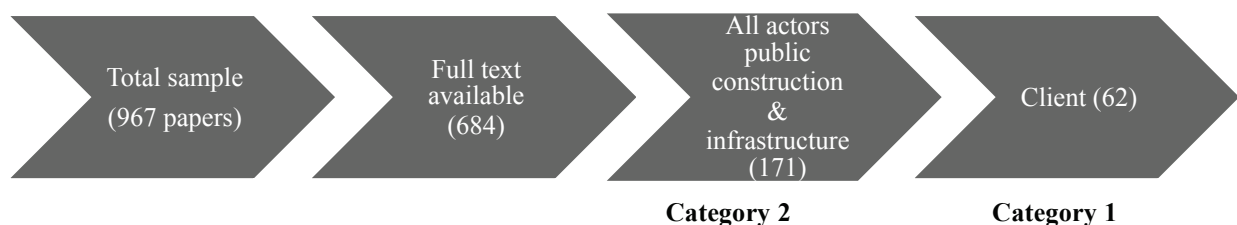
The context of these papers is construction or infrastructure industry, written specifically for or about clients, or considering the client perspective on a (different) subject. These 62 papers are the main source of inspiration for our research agenda.

- *Category 2: second tier papers*

The context of these papers is the construction industry or infrastructure, but the results focus on all stakeholders instead of clients only. When a tool or topic is described that is relevant to the client but not specifically aimed at the use of clients, the paper was also included in this category. These 109 papers provide a background for our research agenda.

The process from 967 to 62 papers is displayed in figure 1. The full list of these papers can be obtained from the authors.

Figure 2: Selection of the papers



2.2 Explorative quantitative analysis

The results of this paper consist of two parts. In the first part we analyse all category 1 and 2 papers on the year of publication, top authors and journals and geographic dispersion (section 3.1-3.4). This analysis is based on the export file of Scopus and JSTOR. We also looked at the government forms of affiliated countries as categorized in the report of the Democracy

Index (The Economist Intelligence Unit, 2013) (section 3.5). In this report a distinction is made between full democracies, flawed democracies, hybrid regimes and authoritarian regimes.

Again both authors read the abstracts (and if necessary the papers) and categorised the context of the research. The research methods of papers were analysed in the same way (sections 3.6). We distinguished between qualitative methods, quantitative methods, mixed methods, argumentation, modelling and other methods.

Finally the papers were categorised on the research theme (section 3.7). Inspired by the roadmap (Haugbølle & Boyd, 2013) and the 4-phase Project Life Cycle (PLC) model (Pinto & Prescott, 1988) we identified five fields of interest on public clients in construction: 1) Operating in the public realm, 2) Organising people, 3) Developing the performances level/brief, 4) Organising the project, and 5) Governing the assets. Themes 2-5 are translations of phases in the PLC: conceptualisation, planning, execution and project termination/use. Theme 1 is an addition to the PLC model emphasising the context of the public sector. In this theme the focus is the need for transparency, accountability and integrity, important issues for public clients. Theme 2 pays attention to the internal organisation of the public client. In order to generate a successful project, it is important to put the right people at the right places and coordinate the projects on a strategic level. Theme 3 concentrates on briefing and establishing the desired performance level of the future facility. Theme 4 regards the tender and procurement phase and the construction phase. Theme 5 focuses on the management of the assets and underlying contractual agreements of the client.

2.3 Explorative network analysis

In the second part of the paper we focus on the connections between all 967 papers in the data set to see how the papers relate to each other, and which papers and topics are important. For this a network overview was created which displays the references as mentioned in the papers. We followed the same method as Chappin and Ligtoet (2014) in their paper on the differences between transition and transformation.

For the network overview the papers from the search query including the references was exported from Scopus and JSTOR into an export file. We then ran the script provided by Chappin and Ligtoet to convert the export file into one that can be imported into the program Gephi. We used Google Refine to clean the data by removing typing errors and combine different spellings of the same reference (for instance P.E.D. Love and P. Love). Finally we imported the file in Gephi, a program which recognises the relation between two documents and connects them in a network (see Chappin & Ligtoet for the details).

Our network on public client literature consists of 16.445 nodes with 17.313 connections. To keep a clear view on the network, the figure only shows nodes with 4 connections or more that are connected to the central network. These are 320 nodes in total. The size of the node refers to the number of connections: the more connections, the bigger the node. The results of this analysis are described in chapter 4.

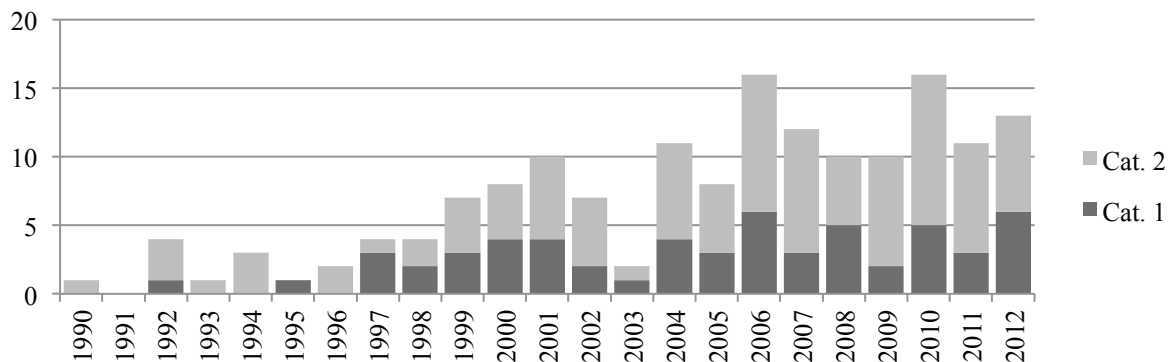
3 RESULTS PART 1: EXPLORATIVE QUANTITATIVE ANALYSIS

3.1 Paper count per year

We found 117 papers on public commissioning. This sample size is comparable to other literature reviews on a specific topic in the construction industry. See for instance Garvin and

Gross (2012) who identified 278 PPP-related papers in infrastructure in a smaller timespan (1997 up until 2010) or Lehtiranta (in press), who found 105 papers on risk management in project management between 2000 and 2012. This is comparable to our size. However, compared to general fields of study such as health care or IT, it is a very limited number. Figure 2 shows the paper count per year. This shows a substantial increase of publications since 1997, in both cat.1 and cat.2-papers. Cat.1-papers, with a main focus on the clients, show a growth from incidentally one paper per year to five per year. Cat. 2-papers increase from around two per year to ten per year.

Figure 3 : Paper count per year

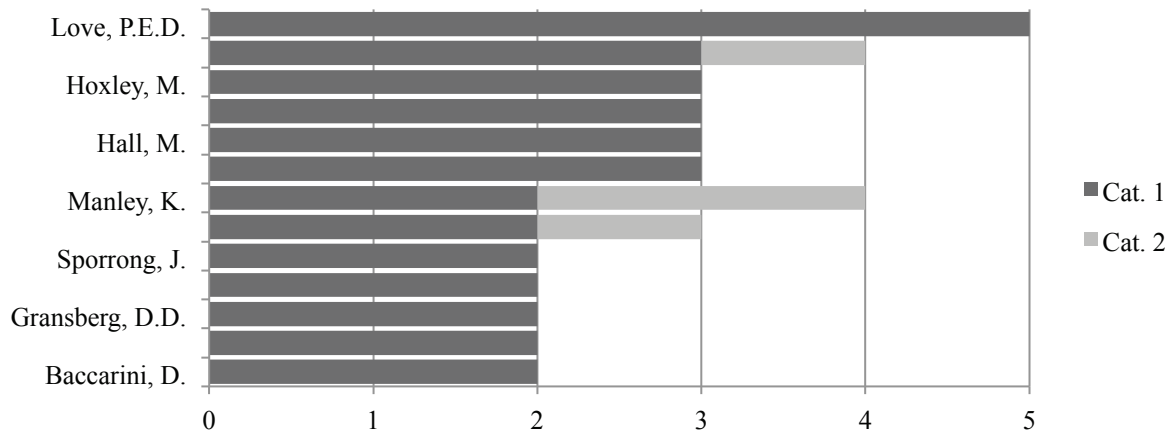


Two points in the graph catch our attention, the first being the increase of papers after 1997. Before 1997, the number of published papers is relatively low. The increase after 1997 can be related to the report of Latham (Constructing the Team, 1994) and the report of Egan (Rethinking Construction, 1998). As shown in section 4, these reports are important links in our data set. The second remarkable point is 2003, which is a notable low point with only one paper per category. We find this gap difficult to explain. The number of papers in surrounding years is the same, so there is no reason to believe that there was a decline in interest in this subject. Since the papers in 2002 and 2004 focus on the same subjects (contractor selection, decision making), it also does not mark a transition from one theme to another. Yet, we noticed that the journals featuring a lot of papers in this data set (Construction Management and Economics, Journal of Construction Engineering and Management, see also section 3.3), are not present in 2003. We therefore assume this dip is merely coincidental.

3.2 Important authors

The number of unique authors is 299. Figure 3 shows the top 13 authors appearing in the search query results are responsible for 34 of the 62 papers in Category 1 (55%). This group of important authors is relatively small. They also often write papers together, which causes a tightly interwoven pattern in the network overview (chapter 4). Based on the disposition between cat.1 and cat.2 papers we conclude that these authors did mainly focus on the client perspective instead of taking all construction stakeholders into account.

Figure 4: Paper count per author (only displaying authors with 2 cat.1-papers or more)



Looking at the topics addressed in the papers, we notice a strong interest in public procurement, originating from Australia and the UK. Peter Love of Curtin University of Technology (Australia) wrote, for example, five papers on public sector procurement, and five other authors wrote three cat.1-papers: Peter Davis (also Curtin University) and David Edwards (Loughborough University/ Birmingham City University, UK), both co-author of three of the five papers on this topic by Love. Mark Hall (University of Bath/Manchester Metropolitan University, UK) and Robin Holt (University of Bath, UK) wrote three papers together about project management in the UK. Michael Hoxley (Anglia Polytechnic University/Nottingham Trent University, UK) authored 3 papers on service quality in the public sector.

3.3 Important journals

Figure 4 shows the kind of journals in which the papers were published. There are 81 unique journals in our results. They can be generally divided in two groups: one focusing on construction and engineering and one on management sciences and governance.

Two journals are ahead in number of publications: Construction Management and Economics (published by Routledge), with 23 papers in total and Journal of Construction Engineering and Management (American Society of Civil Engineers) with 17 relevant papers. Our focus on the public sector shows in the journal on the third place, International Journal of Public Sector Management (Inderscience) and Public Performance & Management Review (M.E. Sharpe) on the eighth place. These journals do not feature cat.2-papers, which shows that the papers they publish focus not only on construction, but when they do, they are regarded cat.1-papers.

Figure 5: Paper count per journal (only displaying journals with 2 cat.1-papers or more)



The papers in place three to six feature a larger share cat.2-papers than cat.1-papers. We believe this is because of a wider scope on construction actors, visible from the titles: review, project management, and environment.

3.4 Geographic dispersion

Figure 5 shows the geographic dispersion of the papers. 50% of the cat.1-papers originate from Europe (inner circle). The majority is produced in the United Kingdom. Sweden, The Netherlands and Poland are the other European producers of cat.1-papers. Asia, North America and Australia are responsible for 1/6 of the remaining papers. Respectively Hong Kong, United States and Australia produced the largest number of papers from their continent.

The cat.2-papers (outer circle) show a different image. The share of Asian authors is twice as big, constituting mostly of contributions from Hong Kong and Taiwan. The European, North American and Australian shares are smaller. From these findings we conclude that in Europe the focus on public commissioning and especially the client is the biggest. In Asia the debate on public commissioning concentrates on all actors, instead of only the client.

3.5 Forms of government

Elaborating on the previous section we determined to what extend the data collection of the selected papers was done in a democratic environment (figure 6). The papers were distinguished between full democracies, flawed democracies, hybrid regimes and authoritarian regimes, based on the Democracy Index of 2012 (The Economist Intelligence Unit, 2013). Almost 80% of the cat.1-papers are from a full democracy. The top four countries (UK, US, Australia and Sweden, together 68%) are full democracies. There is only one paper in the authoritarian and two in the hybrid category. This form of government possibly effects public commissioning, especially in the field of transparency and accountability.

In the cat.2-paper the share of full democracy is significantly smaller. This is connected to the increase of papers from Asia in this category. Hong Kong, a flawed democracy, mainly contributed to this share. The increase in authoritarian papers is influenced by papers from China. It is clear that our focus, public client commissioning, receives more attention in democratic countries.

Figure 5: Paper count per continent

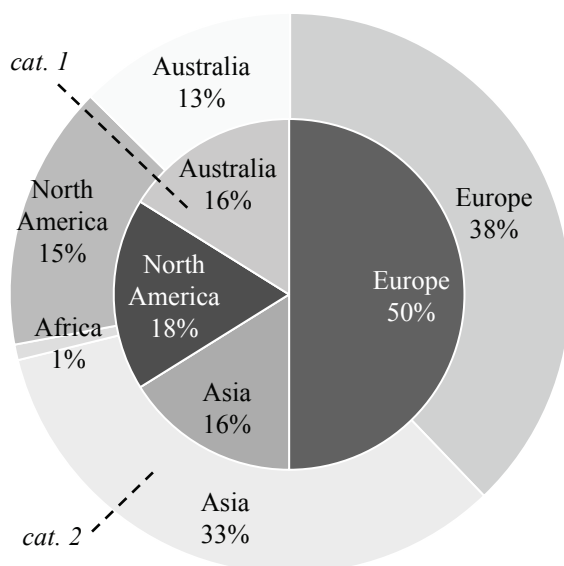
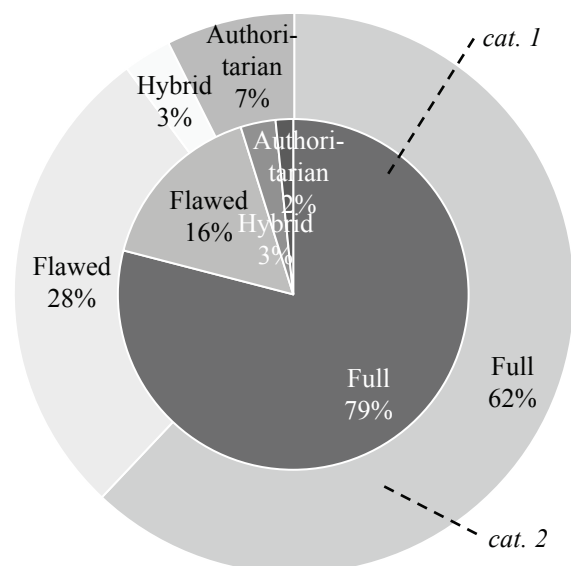


Figure 6: Form of government in countries where papers were written



3.6 Research methods

To determine the nature of this research field, we also analysed the research methods. We found that qualitative research is a majority in cat.1 and cat.2-papers (53% and 43%, see figure 7). This shows the nature of this field: multidisciplinary research with a relatively small amount of traditional engineering.

For the cat.2-papers the share of qualitative research is smaller compared to the first tier papers, whereas modelling has a substantial bigger share. This difference appears to relate to the amount of Asian papers in this category and their preference for quantitative studies and modelling. Especially the modelling of contractor selections is a popular research area. Based on this analysis we conclude that the majority of the cat.1-papers describe public commissioning from a sociological point of view in identifying the complexity of the phenomenon, while cat.2-papers are more focused on unravelling reality by modelling and conducting surveys.

3.7 Themes of papers

To map which topics in public commissioning are well researched and which not, we divided the papers in the five client themes: acting in the public realm, organising people, developing the brief, project organisation and governing assets. As shown in figure 8 most cat.1-papers deal with theme 4 – the project organisation. Common topics in this theme are contractor selection, project performance and project management. The other themes have a considerable smaller share, of which theme 1 (Governing the assets) is clearly the smallest. The image for cat.2-papers is the same: most papers are about organising the project. This shows that generally most attention is given to the project organisation, whether the papers focus on the client or on all stakeholders. Not much attention is given to operating the public realm, organising the people, developing the brief or governing the assets.

Figure 6: Research methods

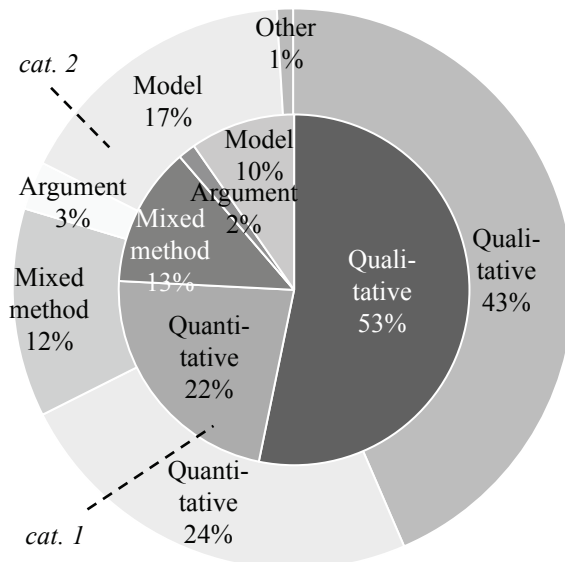
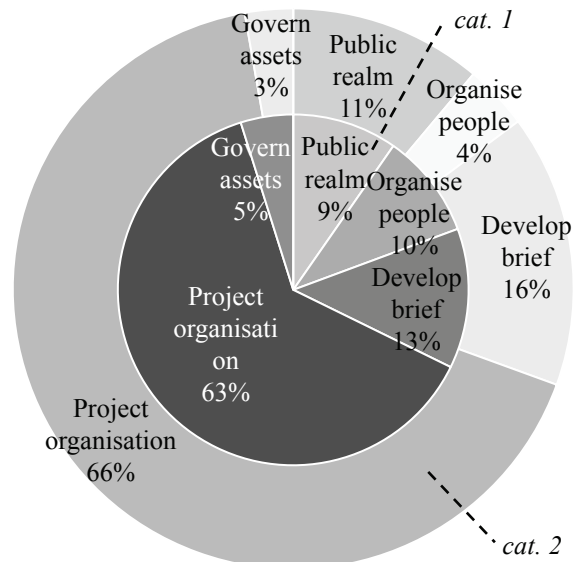


Figure 7: Themes of papers



4 RESULTS PART 2: NETWORK ANALYSIS

4.1 Themed groups

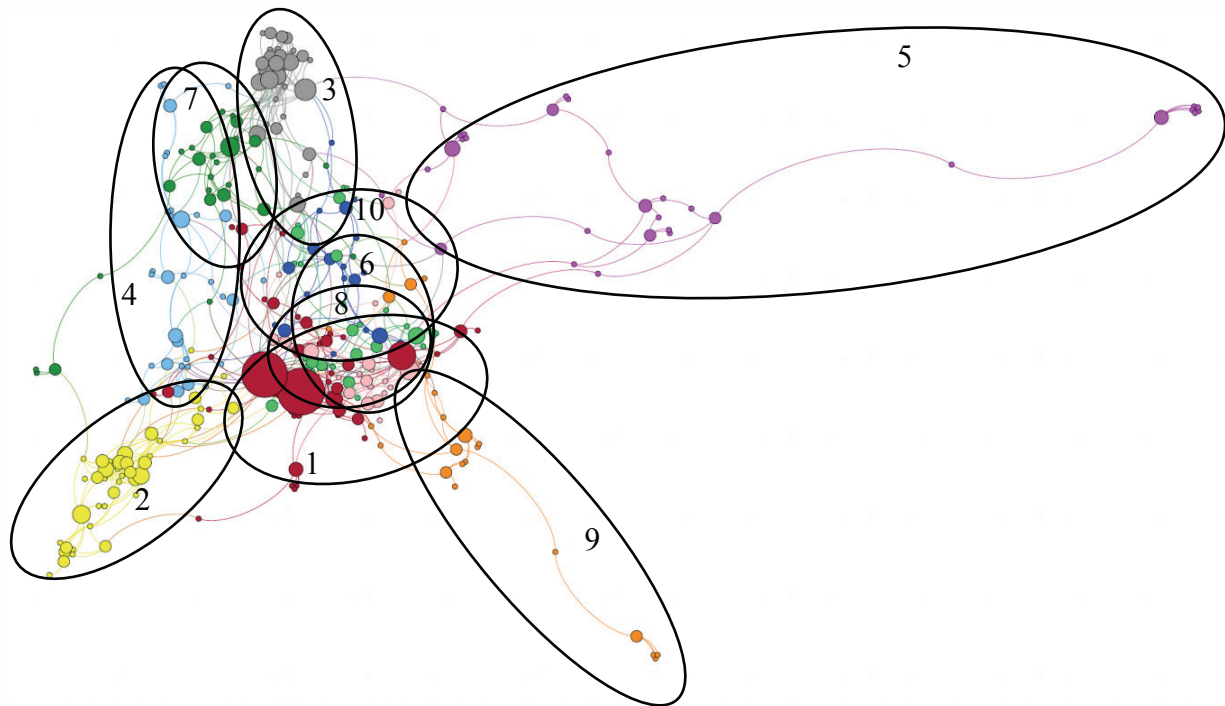
In the second part of our paper we discuss the results of a network analysis of the total sample of 967 papers. As indicated in section 2.3 the network analysis consists of a closely-knitted network of 320 nodes with a large number of mutual connections (figure 9). Of the 320 nodes, 42 belong to papers in category 1. This means 20 papers are not in the network, mainly because they are recent and have to date not been referred to. Only half of the category 2 papers is present in the network: 56 of 109. This means they do not yet have a strong connection to the core of the network, which consists mainly of papers on the construction industry and infrastructure. Because they appear in our search results, they should be relevant for our research field.

The software Gephi categorised the nodes on the basis of mutual connections. Based on this categorisation, ten main groups were identified:

1. Collaboration: this group contains the two biggest nodes related to the Latham and Egan report. Key words of this group are: team organisation, collaboration, innovation, and case study research. This shows that most papers focus on a better way to collaborate (by partnering, supply chain management and/or innovative procurement), mostly done by investigating cases. Together with groups 6 (modernising construction), 8 (innovation) and 10 (public project management) it is one of the main themes of the network, with many connections with other themes and papers.
2. Contractor selection: keywords are contractors, selections, competitive bids, decision criteria. This group is situated at the edge of the network, which means it has few(er) connections to other groups. As a group however, it is coherent, indicating that the authors refer a lot to each other's work, but not so much to papers outside this theme.
3. Project performance: this group focuses on construction performance, especially on cost and time overruns of projects. Like group 2 (contractor selection) it is a coherent group. It is also at the edge, but less remote than group 2. This means the number of connections to other groups is higher than group 2.
4. Service delivery: group 4 focuses on delivery methods (Design & Build and Joint Ventures) and on service quality. It is a widely dispersed group, which indicates not much internal referencing. The number of connections to other themes on the other hand is large. The references to group 1, 2 and 7 show its relevance for team organisation, contractor selection, and causes of time and cost overruns.
5. Public private collaboration: this group is the most widespread group. This means there is a small number of internal connections. It is also at the edge of the network, showing it does not have a lot of topics in common with other groups. Keywords are private finance initiative, public private partnerships, public sector and democracy.
6. Modernising construction: this group focuses on cooperation and modernising construction. Being in the centre of the network it is a group with many connections to other themes. This indicates that cooperation and modernising construction are important themes in our data set. These themes are often subject to qualitative research.
7. Delay and cost overruns: this group shared similarities with group 3 (project performance). However, being closer to group 4 (service delivery) the publication concerns are delay and cost overruns combined with delivery methods and public private partnerships.
8. Innovation: this group shows similarities with group 1 (collaboration) and 6 (modernising construction). Main themes are innovation in construction and procurement innovation. Other important terms are case study research and qualitative research, which show the type of research of this group similar to group 1, 6 and 10.

9. Integrity: this is a dispersed group at the edge of the network. It focuses on professional ethics, better construction briefing, and collusion.
10. Public project management: this group also positioned in the centre of the network. It combines research on project management, project procurement, and public sector clients. The group is connected to group 5 (public private collaboration) so it is strongly focused on public sector topics.

Figure 8 Network of papers



4.2 Network results

Our network analysis shows a number of interesting findings, which also connects to the quantitative exploration of the sample in the first part of our paper. First, we clearly recognise the two groups of journals as identified in section 4.1.3. Although the management and purchasing papers are mainly concentrated in groups 4 and 10, the network shows that public commissioning is a multidisciplinary field studied by both construction/engineering and (public) management/purchasing researchers.

Four groups (Collaboration, Modernising construction, Innovation and Public project management) are centrally positioned in the network. The cross references between these groups signifies the importance of these papers for the research agenda. However, we also found themes that are at the core of public commissioning, such as public sector, democracy, professional ethics and (better) briefing (groups 5 and 9), are at the edge of the network. This signifies a weak link to other papers. The number of papers in those groups is also small. This is in line with our findings in section 3.7. Of the ten groups identified, seven (group 1-4, 7, 8 and 10) focus on the execution phase of a project.

We therefore conclude that most of the research done on public commissioning is related to project management, procurement, and performance. It is merely performed by a relatively

limited group of people, often referring to each other's work. Little attention is paid to other topics and therefore less prominent in our network. In order to develop a balanced field of research that represents the full scope and complexity of operating as a client in the public domain, future research should incorporate the character of the public private collaboration and general themes of construction innovation, integrity and other public values.

5 CONCLUSION AND RESEARCH AGENDA

5.1 Conclusion

The goal of this paper was to set up a research agenda for public commissioning in construction. We investigated what is currently known about this topic and what can be done to increase the level of (scientific) knowledge. We conclude that the number of papers on public commissioning is limited: our total sample included 967 publications that somehow relate to clients. In the time span of 1990 to 2013, only 62 papers were directly connected to public clients in the construction industry. This number increases from 1 to 12 papers per year, indicating a growing field of science. The majority of these papers are produced by a small number of authors from Europe and Australia, and published in only a few journals.

Most research papers appear to have a limited scope. The explorative quantitative analysis showed that more than half of the relevant papers focused on project management, contractor selection and project performance. This was confirmed by the network analysis, which revealed that these papers are situated in the centre of the network. Furthermore, two-third of the selected papers use qualitative research methods such as case studies and interviews.

The journals publishing relevant articles for client research can be divided into two categories: a large group focusing on construction and engineering, and a smaller one on management sciences and governance. Although some topics are relevant for the construction industry, most of the papers do not seem to acknowledge public commissioning as a separate field. We also found that the core of the network concentrates on two levels: the project level and the industry level. The organisational level is missing. We believe this is the main concern of the client.

5.2 Reflection

Our results share similarities to the roadmap of Haugbølle & Boyd (2013). The results from the literature review underpin the importance of the domains. The domains identified in the roadmap are comparable to the topics we found. Compared to the roadmap, our literature review adds prioritisation and also concretises relevant research fields. Our findings, for example show that domain 2 Business and Users (where the organisation of the achievement is enacted) is related to our topic 4 (Organising the project). We found that there has been much interest on this topic. We therefore believe that more focus on the other domains is required.

Determining the relevant papers for public construction clients is an evolving process. One example is the fact that the term "purchasing" was not included in our original query. Yet, from the network analysis we found that purchasing is an important topic in public sector literature. As Murray (2009) indicates the terms commissioning, procurement and purchasing, are often interchanged.

When looking at the results from the query, almost no papers on legal issues were included. This can be attributed to the fact that Scopus mainly focuses on science, technology and social sciences and that we excluded papers we were unable to access. This effect apparently was not compensated by JSTOR, which does feature law journals. To broaden the scope of the query, the query should be performed at other databases or universities, since the kind of subscriptions to particular journals differs between libraries.

5.3 Research agenda

We suggest that in order to describe and investigate the full spectrum of public commissioning, the scope should be broadened towards operating in the public domain, the internal organisation of the client, briefing and asset management. A strong connection to adjacent research fields such as public administration, law and organisation sciences may support the further development of the field. We found inspiration in other fields that came across in our search query such as IT, healthcare, urban planning, and infrastructure management. A research agenda can connect these fields to that of public clients in construction, improve the level of knowledge to enhance the position of the public client in construction. The goal of the research agenda will therefore be twofold, comprising both new research and valorising existing knowledge.

Firstly, the themes that have not fully been addressed in previous research could be developed in the further. Since most of the previous work concentrates on project related issues, our focus is on two topics: 1) The client as a professional public organisation, and 2) The client as a strategic asset manager. Topic 1 elaborates on the organisational structure and competences the client. Having the right people in the right place will not only enhance the internal organisation, but also impact project performance (Van Weele, 2009). This in turn could improve the image of the project and the commissioning body as separate entity. Especially in times when budget cuts are prominent and transparency, integrity and accountability are important values (Jørgensen & Bozeman, 2007), the perception of professionalism is an important feature for public clients. Adjacent fields, such as organisation science, organisational psychology and public administration, could offer interesting theories in addressing these issues.

Secondly, we will focus on strategic asset management. This is strongly related to the aging building stock in the Netherlands and other (European) countries. In the years following World War II, a large amount of dwellings and infrastructure was constructed (Dekker, 1996). This stock has now reached the end of their technical life span, while the demand for new real estate is diminishing. The need for transformation and renovation will therefore become more prominent. Knowledge development in this area strongly relates to architecture, urban planning and heritage of our built environment.

Furthermore, there is a need from practice for practical guidelines and instrumental tools. Despite the availability of existing publications and tacit knowledge, mistakes are still made. This requires a good valorisation strategy that is tuned towards the audience. Our research strategy provides in a practice-oriented research approach, in which practical implications are integrated in the development of theoretical knowledge foundations.

REFERENCES

- Boyd, D., & Chinyio, E. (2008). *Understanding the construction client*. Oxford: Blackwell.
- Chappin, E. J. L., & Ligtoet, A. (2014). Transition and transformation: A bibliometric analysis of two scientific networks researching socio-technical change. *Renewable and Sustainable Energy Reviews*, 30(0), 715-723.
- Crowther, M. A., & Cook, D. J. (2007). Trials and tribulations of systematic reviews and meta-analyses. *Hematology / the Education Program of the American Society of Hematology. American Society of Hematology. Education Program*, 493-497.
- Dekker, R. (1996). Applications of maintenance optimization models: a review and analysis. *Reliability Engineering & System Safety*, 51(3), 229-240.
- Denyer, D., & Neely, A. (2004). Introduction to special issue: innovation and productivity performance in the UK. *International Journal of Management Reviews*, 5(3-4), 131-135.
- Garvin, M., & Gross, M. (2012). Identification, Characterization and Analysis of Selected Research on Transportation Public-Private Partnerships from 1997-2010.
- Hartmann, A., Reymen, I. M. M. J., & Van Oosterom, G. (2008). Factors constituting the innovation adoption environment of public clients. *Building Research and Information*, 36(5), 436-449.
- Haugbølle, K., & Boyd, D. (2013). Clients and Users in Construction (Vol. CIB Publication 374).
- Jørgensen, T. B., & Bozeman, B. (2007). Public Values: An Inventory. *Administration & Society*, 39(3), 354-381.
- Lehtiranta, L. (in press). Risk perceptions and approaches in multi-organizations: A research review 2000–2012. *International Journal of Project Management*(0). doi: <http://dx.doi.org/10.1016/j.ijproman.2013.09.002>
- Morledge, R., & Smith, A. (2013). *Building Procurement*. Chichester: Wiley-Blackwell.
- Murray, J. G. (2009). Towards a common understanding of the differences between purchasing, procurement and commissioning in the UK public sector. *Journal of Purchasing and Supply Management*, 15(3), 198-202.
- Oxman, A. D. (1994). Checklists for review articles. *BMJ: British Medical Journal*, 309(6955), 648.
- Pinto, J. K., & Prescott, J. E. (1988). Variations in Critical Success Factors Over the Stages in the Project Life Cycle. *Journal of Management*, 14(1), 5-18
- The Economist Intelligence Unit. (2013). Democracy index 2012.
- Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management*, 14(3), 207-222.
- Van Weele, A. J. (2009). *Purchasing & Supply Chain Management: Analysis, Strategy, Planning and Practice*: Cengage Learning.
- Winch, G. M. (2010). *Managing Construction Projects*. Chichester: Wiley-Blackwell.

APPENDIX

1 Search query Scopus

TITLE-ABS-KEY(public OR government) AND (TITLE-ABS-KEY({local authority} OR {local authorities} OR client OR commissione* OR commissioning OR {owner} OR {parliament})) AND TITLE-ABS-KEY(construction OR infrastructure OR {real estate} OR architectur*) AND TITLE-ABS-KEY({asset management} OR {portfolio management} OR {project management} OR {process management} OR performance OR procur* OR brief OR briefing OR partnering OR {public private partnership} OR {public-private partnership} OR p3 OR ppp OR assessment OR governance OR maintenance OR project OR tender* OR build* OR housing OR {facility management} OR transportation)) AND SUBJAREA(mult OR ceng OR engi OR mult OR arts OR busi OR deci OR psyc OR soci) AND PUBYEAR > 1989 AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "re") OR LIMIT-TO(DOCTYPE, "cr"))

2 Search queries JSTOR

("public client"~25 AND "client construction"~25)
("public client"~25 AND "client infrastructure"~25)
("public client"~25 AND "client estate"~25)
("public client"~25 AND "client architecture"~25)

4.2

DIFFERENT PERSPECTIVES ON FACILITIES MANAGEMENT TO INCORPORATE IN BIM

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ABSTRACT

Purpose: This paper will review the value of Building Information Modelling (BIM) and demonstrate how the early integration of Facilities Management (FM) within BIM can enhance building performance from the perspectives of the building delivery team, facilities management team and building occupants.

Background: It is proposed that involvement of the facility management team at an early design stage can contribute towards enhancing building performance, but this requires a multiple perspective of FM to be adopted. BIM has the potential to be used for managing facilities as it provides extensive information about all physical assets in the building.

Approach: Pilot data has been acquired from a newly built and operated university building in the United Kingdom using interviews to capture information from these different perspectives.

Results: The differences in perspectives are presented based on the responses collected from the interviews. Three parameters are used to compare and analyse them highlighting how these differences are difficult to accommodate in building design

Practical implications: The paper proposes a structure for BIM to accommodate the different perspectives on FM from the building design stage. This leads to the necessity of involving the facility management team during the design and construction process.

Research limitations: The proposed structure is based on the responses from the interviews, and may apply to other educational buildings, but may not be generalised to all buildings.

Originality/value: This paper provides an initial platform towards better understanding of the contribution of facilities management in the design process to improve building performance with the use of BIM.

Keywords: Building Information Modelling (BIM), Building performance, Facility management (FM), Soft systems

1 INTRODUCTION

Buildings are the containers of many social activities where this imposes the need for an efficient building design that can operate effectively, support these activities and can be maintained for a longer period. Studies of building performance have shown that buildings do not perform as intended and are a barrier to productivity (Cooper, 2001). Building performance is a complex concept that has been difficult to measure and to incorporate into building design. The advantage of being able to make buildings to be a productive workspace for their occupants is essential both financially and organisationally. Facilities management (FM) supports maintaining the building performance by managing operations by integrating people, place, process and technology to ensure functionality of the built environment (IFMA, 2013). Nevertheless, the challenge of integrating sophisticated multidisciplinary systems within the building to perform as intended once the building starts operating has increased the difficulty of evaluating building performance (Mahadev, 2010). The advent of BIM provides the opportunity to predict building performance. BIM collects extensive data and performs calculations in real time to feedback information to the building designers. This paper reports on part of a wider study that is researching this use of BIM in the design process to deliver building performance during design and the role of FM to deliver performance. The adoption of multiple perspectives represents one of the bases of soft systems where different perspectives are essential in solving real life issues (Mehregan *et al.*, 2012). In addition, soft systems enable effective collaboration among stakeholders negotiating different actions that can be taken to improve situations. This paper considers the way that different perspectives on facilities held by the building delivery team, facility management team and building occupants affect building performance. It uses semi-structured interviews to capture these perspectives in the context of a newly completed building. Differences in perspectives are analysed to propose an information framework to incorporate these different perspectives on facilities into BIM model.

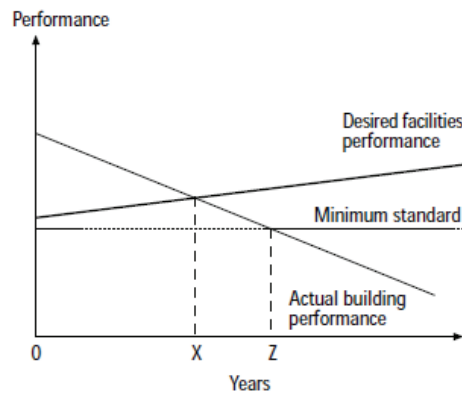
2 STATE OF THE ART

There is a growing interest in the area of building performance as buildings do not perform as intended. Ensuring the intended performance and operation of buildings will extend the service-life of buildings (Dino and Stouffs, 2014). One of the major causes of inefficient building operation is inaccurate evaluation of building performance at the design stage (O'Donnell *et al.*, 2013). This is because building performance can be interpreted in many different ways such as evaluating it against the identified requirements for the building or how the building is being perceived by users, and thus it is an interdisciplinary concept (Alexander, 2011).

Inevitably, the performance of any building declines over time (see figure 1) and this is due to many factors including those associated with climate change, technical issues or user misuse (Douglas, 1996). On the other hand, the degree of this decline is claimed to be dependent on how well the facilities support the building (see figure 1) in order to maintain the performance over a longer period of time (Douglas, 1996; Barret and Baldry, 2003). According to British Institute of Facilities Management (2014), facilities management is defined as inte-

grating processes within an organisation in order to maintain the agreed services that support and improve the effectiveness of the primary activities for that organisation. In this context, FM includes hard facilities (e.g. building fabrics, MEP systems) and soft facilities (e.g. catering, security, cleaning) in the building.

Figure 1: Relationship between facility management and building performance (Douglas, 1996)



Facilities management (FM) is also incorporated in the performance of some building aspects such as energy usage by engaging with up-to-date models for energy management, calculation of building's life costs and sustainability certification (Junghans, 2013). Some systems such as computerised maintenance management system (CMMS) have been developed to support facilities and their maintenance performance (Lai and Yik, 2012), but it is yet to be identified what information is to be acquired and to what extent it can be integrated to enhance the facilities' performance. The value of facilities in a building should be considered in the context of its use and as a service provider to extend the life of the building (Alexander, 2011). This supports the need for the building to be considered from a user perspective so as to be efficient for use, and from a facility manager's perspective to be easily maintained. Nevertheless, bridging this multiple perspective gap between FM and building performance needs a tool to manage the complex information and provide this knowledge so that it can be utilised in an effective way. BIM (Building Information Modelling) provides a full design model by integrating all systems (structural, architectural, MEP and HVAC) within one whole model (Porwal and Hewage, 2012) supporting an inter-disciplinary simulation and analysis in a single model (Azhar *et al.*, 2011).

According to British Institute of Facilities Management (2012), BIM currently does not represent a solution or a tool for FM, but it is a process that allows facility managers to inform the designers about the information they need at an early design stage. British Institute of Facilities Management (2012) claims that showing a 3D visualisation of the plant room to building maintenance people using BIM could offer the opportunity for better training and avoid maintenance access problems. One way that BIM is being used for facilities management is the creation of Construction Operation Building Information Exchange (CoBie) structured information which provides spreadsheets of data containing list of equipment, product data sheets, preventive maintenance, etc. (East, 2013). However, the representation of these sheets do not adequately represent the performance of a building from a facilities managers' perspective as they do not reflect the problematical nature of building operation and maintenance (Mayouf and Boyd, 2013).

These current approaches to the development of BIM for facilities management do not acknowledge the differences in viewpoints that occur between different stakeholders in buildings. In fact, BIM effectively only provides a single perspective of information which is contributed by the building delivery team. This has a negative impact on FM operations (British Institute of Facilities Management, 2012) both because it does not accommodate what is necessary for managing building operations and because it does not recognise the different concerns of building users. An effective evaluation of building performance requires multiple perspectives in terms of project stakeholders (designers, facility managers and occupants) to be considered. A multiple perspective would acknowledge the problematic nature of FM in buildings and how it impacts building performance from the perspectives of designers, facility managers and occupants. BIM would enable the involvement of the facility management team, incorporating their requirements and occupants' needs which would enhance the delivery of building performance.

3 APPROACH

The wider research uses a soft systems approach as a process of inquiry into a problematic situation which acknowledges cultural differences and systemic complexity (Mehregan *et al.*, 2012). As part of this work, case study research was conducted on a newly operating (September 2013) university building in the United Kingdom. Interviews were undertaken with members of the building delivery team, the facility management team and building occupants on their perception of building performance.

There were four interviewees from the building delivery team, including the university's estates department (project director, BIM coordinator and BREEAM assessor) and building designer (BIM manager). The selection of these individuals sought to explore any contradictory understanding of building performance even though they belong to the same team. There were two interviewees from the facility management team; a senior facility manager and building services supervisor. This enabled a view of both soft and hard services and the way they should be delivered to satisfy building occupants' needs. There were three interviews with university staff who were chosen to represent the building occupants and had continual daily use of the building. These three groups allow multiple perspectives of facilities on building performance to be explored.

The data was collected individually using semi-structured interviews, as this allows the exploration of more detailed insights about different perspectives on building performance. The use of the interviews in the context of a case study would allow a live reflection on the building itself from a performance perspective and unlike surveys (for example, post-occupancy evaluation), interviews would allow the discussion of different meanings of the idea of performance. The interview questions aimed to investigate the different perspectives with respect to the concept of building performance, role of facilities in the building and how BIM can support achieving the desired building performance. These factors were selected to allow an understanding of: the different perspectives on the performance concept, how facilities management can deliver building performance and how design technology (BIM) can assist in this task. A brief introduction to BIM was provided for the facility management team and building occupants, so as to enable discussion about the sort of information that it would be useful for BIM to include.

4 RESULTS

Respectively, the results present the responses from the building delivery team, facility management team and building occupants. The results represent the responses from interviews are presented for each perspective under three parameters which are: concept of building performance, facilities management role for building performance and BIM value to support building facilities. These three parameters provide a more holistic approach towards understanding the problematical nature of FM, its effect on building performance and BIM value to support it.

4.1 Building delivery team

Table 1: Building delivery team perspective

Role \ Criteria	Concept of building performance	Facilities management role for building performance	BIM value to support building facilities
Project Director	It is about maintaining all levels of understanding of control and maintenance of the building's energy and operation on the long term.	Impacts building life cycle.	Energy assessing and maintenance information.
BIM Coordinator	The performance of the building is to do with energy efficiency and maintenance.	Flexibility and adaptability for the building.	Space and maintenance information.
BREEAM Assessor	It is based on energy efficiency and how the building can function adequately to meet the needs of the users.	Delivering sustainability.	Facilities information.
Architect (BIM Manager)	It is about maintaining the balance between aesthetics, robustness, durability, thermal comfort, levels of natural and artificial light, energy usage, flexibility to suit changing uses, acoustic performance, capital budget, on-going maintenance costs, clarity of building diagram and organisation of spaces to avoid clutter of imposed signage, integration of services with structure and building fabric and accessibility of building and its uses to all.	Occupants' satisfaction and maximize building assets for the most efficient usage.	Allows optimisation of layouts when modelling required access for plant maintenance or replacement which in return allows maintenance to be planned without unnecessary disruption to the users.

4.2 Facility management team

Table 2: Facility management team perspective and their standing point with BIM involvement in the process

Role \ Criteria	Concept of building performance	Facilities management role for building performance	BIM value to support building facilities
Facility Manager	The building needs to function in a way that	The middle connection between occupants and	Ease of information retrieval especially for operation and

	keeps the occupants comfortable and it also depends on from what perspective you look at it.	building design team.	<p>maintenance manuals.</p> <p>It would help if BIM can find the specification of a particular item.</p> <p>Benchmarking the flexibility to accommodate changes.</p>
Building Services Supervisor	Everything in the building should be in working order and what the customer needs is there for them.	Maintain the building performance for a long period and they represent the undercover power of the building.	<p>It would show the facilities which can or cannot be removed from a space.</p> <p>Engaging BMS (building management system) with BIM.</p>

4.3 Building occupants

Table 3: Building occupants perspective and their expectations of BIM involvement in the process

Position \ Criteria	Concept of building performance	Facilities management role for building performance	BIM value to support building facilities
Senior Lecturer	The way that the building performs as a result of the planning process by the various ranges of disciplines which in total should allow me to do my work.	<p>It should contribute towards the health and safety for the occupants.</p> <p>It occupies a major role in the working environment.</p>	<p>Occupants should be informed about the how the building is functioning.</p> <p>Occupants can contribute towards some of the health and safety issues associated with the design of the building.</p> <p>Space settings should be informed to the occupants.</p>
Senior Lecturer	It has to support my needs as an occupant to do the job assigned to me.	<p>Facilities should be where you actually need them.</p> <p>Should not have any adverse effect on occupants' health and safety.</p> <p>Occupants should be informed about who to tell about any issues arising.</p>	<p>Should allow occupants to know which facilities are movable and which ones are fixed.</p> <p>Check the facilities locations and whether they conflict with the access pathways within the building.</p> <p>Noise level of facilities within open spaces.</p>
Deputy Head of a School	It depends on what the building is going to be for; there are several parameters to measure like feeling, heat comfort, and connectivity between spaces among the building.	<p>Functionality and the quality of its work.</p> <p>Should be interactive with the users of the building.</p> <p>People should have an easy access to feedback about facilities.</p>	<p>Some noise levels from heating and cooling systems.</p> <p>Occupants to be informed about certain aspects within the building.</p> <p>Facility management should interact with users in a way that allow them to report useful information back to the designer.</p>

5 PRACTICAL IMPLICATIONS

The data from the interviews presented in the previous section provides an insight into the problematic nature of the delivery of building performance. Three issues will be discussed. First, the singular nature of the concept will be challenged and the need for multiple perspectives illustrated. Second, the role of facilities management in delivering building performance in building operation will be outlined. Finally, the requirements for BIM to help this provision will be presented.

5.1. Concept of building performance

The interview evidence demonstrates that the three groups see building performance in different ways. Indeed even within the building delivery team the concept was not understood in the same way, although all saw managing energy as part of building performance. These different understandings related to their disciplinary backgrounds. The BIM manager (project's architect) provided the more holistic definition also relating to aesthetics and organisation of space. The facility management team saw building performance as the ease of maintaining facilities within the building and the functionality of building facilities to serve the occupants' needs. The occupants on the other hand claimed that good building performance should allow them to do their daily job comfortably. Each of these groups sees building performance differently depending on their needs. The success of a building is multi-dimensional but it is critical that it works for the occupants who must be productive in their practice. The facilities management team did understand this but could not explain this in detail or show its application in practice. The different perspectives for building performance demonstrate the necessity for a more holistic approach for building design and operation that accommodates these differences.

5.2. Facilities management role for building performance

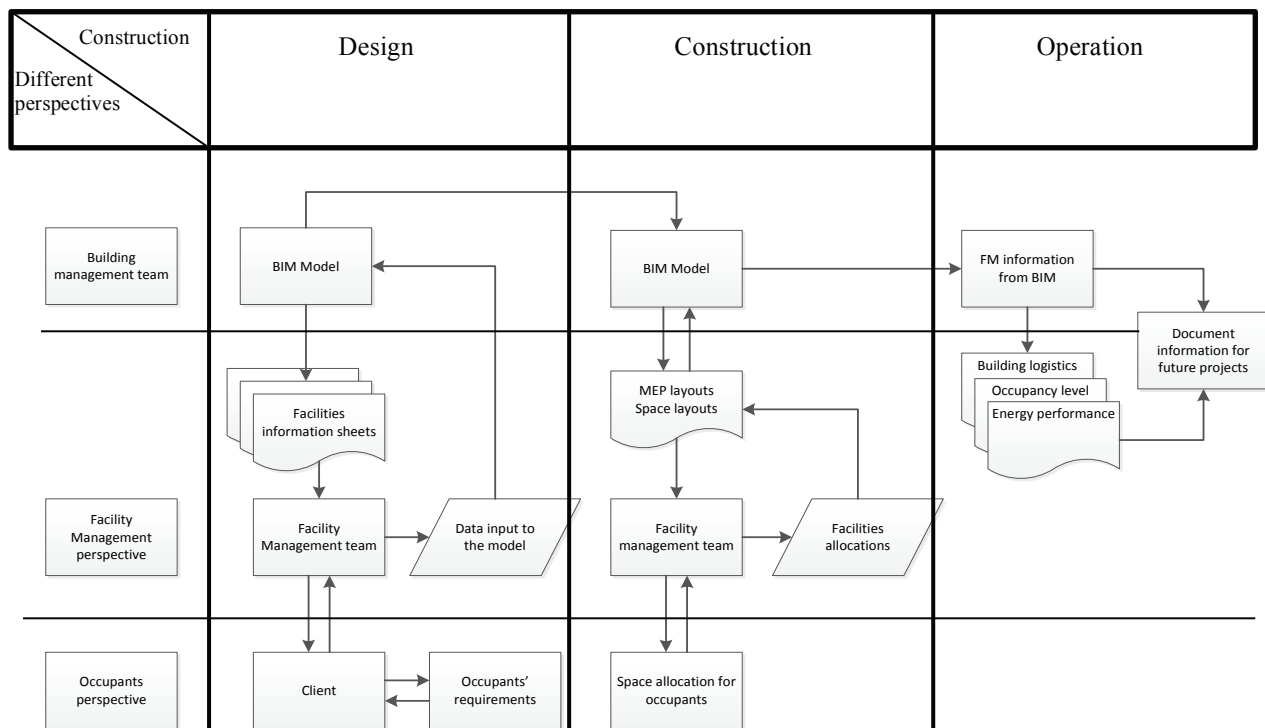
The facility management team have a different perspective on building performance but can only influence this as part of building operations. They focus on maintenance and management issues of the building thus necessitating easy monitoring of facilities to report problems and manage the facilities to maintain long-term operation of the building. They did understand the need to maintain the facilities for occupants' satisfaction but are only able to engage with this in a reactive way when occupants report issues or make complaints. Most importantly, the facility manager pointed out the difficulty of retrieving facilities information especially for maintenance; currently this is only available in operation and maintenance manuals. The facility management team are aware that the layout of the mechanical, electrical and plumbing systems in the building has a direct impact on their ability to maintain efficiency but have little control over this. The layout of public and private spaces and the relation of the services to these also influence other factors like noise levels and usability again these are dealt with only when problems arise. The ability of the facilities management team to deliver building performance is very limited both for the maintenance of facilities and the accommodation of occupants needs. Such issues show the need for multiple perspectives in the consideration of facilities in the building at the design stage. It is claimed by Jensen *et al.* (2012) that incorporating different stakeholders perspectives into FM would have a major impact on the value of FM. This implies the necessity of involving the facility management team at an early design stage by giving them the means to work through their tasks.

5.3. BIM value to support building facilities

As discussed in the previous sections, building performance is seen differently and the facilities team is not able to proactively deliver building performance. This paper argues that BIM has the potential accommodate different perspectives and to engage all parties more effectively in the design process to deliver building performance. In particular, for the facilities management team, BIM can bring greater and more effective information for operations and maintenance through this being included in the model. The model would allow them to check the equipment specification and benchmark the flexibility to accommodate changes. Although, not identified strongly by the facilities management team, they were aware that they would require more involvement early in the design stage in order to provide better building performance. In these respects, BIM should represent a useful collaborative platform where fragmented bits of information can all be taken in consideration to achieve overall better building performance.

Nevertheless, as claimed by Wiesner *et al* (2011), data models currently lack sufficiently structured information for use by facility management team and so this remains as an obstacle for BIM to be useful for FM. Rasys *et al.*, (2013) also point out that current existing information integration uses a mediator engine to represent heterogeneous data sources as if it were a single data sheet. This illustrates that although BIM could support the integration of the three perspectives, information is not currently available which serves the needs of each perspective. Figure 2 proposes how different perspectives on building performance can be incorporated into BIM.

Figure 2: Proposed framework for FM information incorporation among all stakeholders



This illustrates how at the design stage, documents with respect to facilities information (e.g. their location, function, heating or cooling) can be shared with the facility management team to help them to understand FM and occupants' needs. This would raise the designer's awareness of maintenance factors for the facilities, the effect on occupants' of possible breakdowns of some facilities (e.g. HVAC) and reduce costs as changes can be applied at this stage before commencing to the construction phase.

During the construction phase, the facility management team can integrate the finalized Mechanical, Electrical and Plumbing (MEP) layouts into the building's building operation management system which can also measure performance of the building. Additionally, the space layouts could also be provided to the facility manager through the BIM model as they are more aware of the possible noise levels, maximum capacity for occupants and accessibility for users within the building and can therefore assist the delivery of better building performance.

6 CONCLUSION

This research aimed to investigate the value of facilities in improving building performance and how BIM can facilitate the delivery of different perspectives with respect to facilities in the building. Literature showed that the value of facilities plays a major role through the life cycle of the building. BIM provides information integration and supports coordination among those involved in building delivery by integrating interdisciplinary systems in a single model. Interviews showed multiple perspectives of building performance, which contribute to buildings not performing as intended. The facility management team are limited in their ability to support building performance and need to be involved during design. BIM provides the opportunity for this to happen. The practical implications of this research will be to incorporate the information needs of facility managers in the BIM model in a way that connects the building delivery team and client (including occupants). The proposed inclusion of FM information would raise the awareness for BIM coordinators of the sort of information that should be collected through building delivery. It is believed that with BIM capabilities, the gap of building performance can be facilitated through a more holistic multiple perspective approach to have a more effective integration of building facilities.

REFERENCES

- Alexander, K. (2011), "Building Control and Performance: As if people and the planet matter", *Procedia Engineering*, 20, pp. 1 – 11.
- Azhar, S., Carlton, W. A., Olsen, D. and Ahmed, I. (2011), "Building information modelling for sustainable design and LEED rating analysis", *Automation in Construction*, 20(2), pp. 217 – 224.
- Barret, P. and Baldry, D. (2003), *Facilities Management: Towards Best Practice*, Blackwell, Oxford.
- British Institute of Facilities Management (2012), "BIM and FM: Bridging The Gap For Success", available at: www.bifm.org.uk/bifm/knowledge/FMleadersForum (accessed 30 January 2014).
- British Institute of Facilities Management (2014), "Facilities Management Introduction", available at: www.bifm.org.uk/bifm/about/facilities (accessed 28 January 2014).

- Cooper, I. (2001), "Post-occupancy evaluation – where are you?", *Building Research and Information*, 29(2), pp. 85 – 102.
- Dino, I. G. and Stouffs, R. (2014), "Evaluation of reference modeling for building performance assessment", *Automation in Construction*, 40, pp. 44 – 59.
- Douglas, (1996), "Building Performance and its relevance to facilities management", *Facilities*, 14(3), pp. 23 – 32.
- East, E. W. (2013), "Construction Operations Building Information Exchange", available at: <http://www.wbdg.org/resources/cobie.php> (accessed 12 November 2013).
- International Facility Management Association (2013), "What is FM?", available at: <http://www.ifma.org/know-base/browse/what-is-fm-> (accessed 12 February 2014).
- Jensen, P., Van der Voordt, T., Coenen, C., Von Feltern, D., Londholm, A. L., Balslev, Nielsen, S., Riratanaphong, C. and Pfenninger, M. (2012), "In search for the added value of FM: what we know and what we need to learn", *Facilities*, 30 (5/6), pp. 199 – 217.
- Junghans, A. (2013), "Decision support model for energy-efficient improvement of entire building stocks", *Facilities*, 31(3/4), pp. 173 – 184.
- Lai, J. H. K. and Yik, F. W. H. (2012), "Hotel engineering facilities: A case study of maintenance performance", *International Journal of Hospitality Management*, 31, pp. 229 – 235.
- Mahadev, R. (2010), "Complexity in building design", *3rd International Holcim Forum in Mexico*.
- Mayouf, M. and Boyd, D. (2013), "Exploring the problematical nature of building performance in BIM representations", in Boyd, D. (ed.) (2013) *BIM management and interoperability: papers from an ARCOM Doctoral Workshop*, ARCOM/Birmingham City University.
- Mehregan, M. R., Hosseinzadeh, M. and Kazemi, A. (2012), "An application of Soft System Methodology", *International Conference on Leadership, Technology and Innovation Management*, 41, pp. 426 – 433.
- O'Donnell, J., Corry, E., Souleiman, H., Keane, M. and Curry, E. (2013), "Building performance optimization using cross-domain scenario modelling, linked data, and complex event processing", *Building and Environment*, 62, pp. 102 – 111.
- Porwal, A. and Hewage, K. N. (2012), "Building Information Modelling (BIM) partnering framework for public construction projects", *Automation in Construction*, 31, pp. 204 – 214.
- Rasys, E., Hodds, M., Dawood, N. and Kassem, M. (2013), "A Web3D enabled information integration framework for facility management", *Proceedings of the 13th International Conference on Construction Applications of Virtual Reality*, 30 – 31 October, London, UK.
- Wiesner, A., Morbach, J. and Marquardt, W. (2011), "Information integration in chemical process engineering based on semantic technologies", *Computers and Chemical Engineering*, 35(1), pp. 692 – 708.

4.3

THE SHARED BUILDING PORTFOLIO: AN EXPLORATION AND TYPOLOGY

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ABSTRACT

Purpose: The purpose of this paper is to explore shared-use of facilities as a concept that can help organizations to make better, more sustainable use of their building portfolios. The practical aim is to present a typology to help classify, describe and evaluate the different options for sharing facilities from a facility manager's point of view.

Background (State of the Art): Space management literature provides examples and concepts for sharing space, such as 'hot-desking', within a given organisational and physical setting. However, this literature rarely deals with sharing on a building level or between organisations. Literature on the so-called 'sharing economy' deals with sharing itself, but not on buildings and the management of these. The shared building portfolio, the topic of this paper, draws from both of these.

Approach: The paper is the result of a first, explorative study of the topic. Its contents are based on a literature review, a mapping of 20 examples from Europe, USA and Australia, and on primary data from interviews with selected key players in Denmark. The study has been cross sectional, the approach inductive and the overall research philosophy pragmatism.

Results: The typology classifies 4 types of sharing and illustrates ways of organizing and managing the sharing of facilities between different people, building owners and organisations.

Practical Implications: The presented typology is intended for both researchers and practitioners such as property managers of municipalities and larger companies. It can help them get a better understanding of how they can minimize the need for building new by better utilization of the existing building stock for increased sustainability or as a corporate-social-responsibility activity.

Research limitations: The typology is a work in progress and the result of a first exploration of the concept of shared facilities and does not claim to be fully comprehensive or final.

Keywords: Shared space, Shared economy, Sustainability, Facilities Management, Portfolio management

1. INTRODUCTION

Is it possible to make better use of buildings? Is there a hidden potential in surplus space and underused facilities? Anecdotic evidence suggests so. A Dutch dad noticed an empty class room at the elementary school of his daughter. Being self-employed, he considered it an excellent alternative to his workplace at home. Working there would save him the hassle of going back and forth to bring and get his daughter. The school was sympathetic towards his ideas and provided desks, Wi-Fi and a coffee machine. The space is now occupied by a group of self-employed parents, tapping away on their laptops while their kids are having lessons. The parents can use the space for free in return for doing small jobs, such as watching the playground during breaks.

This Dutch school is an excellent example of how to make shared use of a facility. Empty space is being put to use, and the school gets extra hands. The example is part of what seems to be a wider trend towards the sharing of resources. The traditional focus on building new seems to be replaced by an interest in making better use of the existing building stock by intensifying use and allowing different types of users and different uses over time. Think of cowork spaces shared by freelancers and entrepreneurs; educational facilities shared by different schools and community organizations; decrepit industrial buildings shared by artists and start-up companies. It is a trend that is driven by sustainability, accessibility, the economic downturn, and a new ‘sharing mind-set’ among people and organizations.

This paper is a first exploration of the concept of sharing space within public and private organisations. It is meant to play a role in establishing common terms and definitions in relation to the topic of shared space, since literature and media are not always clear when using terms such as ‘sharing resources’ or ‘collaborative consumption’. Furthermore it aims to present a first version of a typology that can be used as a tool for analysis of existing shared spaces, provide a base for dialogue regarding the creation of new, as well as in connection with briefing processes, development of new services etc., especially in regards to property- and space management.

The paper is directed towards larger property owners such as municipalities and companies with a facilities management department. The assumption is that such organisations should take a critical look at their real-estate portfolio and question the need to have ‘own’ buildings, rather than sharing facilities with other organisations or people. From a municipality’s perspective the question could for example be, do we really need to provide all schools and communities with their own sports facilities, playgrounds etc.? For a private company the question can be: Do we really need to build a large expensive lab facility just for ourselves, or can we team up with other companies, and thereby also get a more sustainable and optimized use of the facility, reduced costs or increased synergies? In short; could we share our facilities with others, and what would be the benefits or disadvantages?

2. SHARING AND THE SHARING ECONOMY

Over time there have been countless examples of people sharing space and facilities, with the sharing initiated by just as many different reasons as there are examples. Denmark in the 1850's, and probably many other countries as well, saw the first agricultural, consumer, production and credit cooperatives set up (<http://www.uwcc.wisc.edu>). In the 1900's the development of the first cooperative dwellings in Denmark took place; developments characterized by the individual members purchasing a share certificate and thereby owning a part of the total assets and acquiring the right to use the cooperative facilities connected to the housing association as long as rent is paid to the association. (www.denstoredanske.dk).

So sharing is by no means a new thing, and the focus on sharing has been increasing and decreasing over time. It has been seen in different shapes and forms and has been initiated for different reasons. In the last decade or so though, the concept of sharing has taken another leap, and the term "sharing economy" has seen the light of day, made possible by the internet and social media which have helped provide a platform for sharing-interested individuals, groups and communities.

2.1. The sharing economy

The term 'sharing economy' or 'collaborative economy' is used to describe a new form of sharing developing in societies today; the sharing of anything from a saxophone or a lawnmower to a car or a house. The share economy has by Voight (2013) been described as "*a trend that is reshaping our service-based society*" and by Rosenberg (2013) as "*access rather than ownership*" and a mentality of live light, waste less, to protect the environment. Silver (2013) defines the sharing economy as "*a way of sweating underutilised assets, by building communities around them and turning consumers into providers*", and by Owyang et al. (2013) it is defined as "*...an economic model where ownership and access are shared between corporations, start-ups, and people....*".

The Share Economy, Collaborative Economy or Collaborative consumption, all describing the same overall phenomenon is flourishing on the web and social media. Websites facilitating different kinds of sharing in online communities, local physical communities as well as anonymous via the internet along with blogs discussing the subject have become increasingly numerous (www.alphabet.com; www.thesharehood.org; www.collaborativeconsumption.com ; www.nesta.org.uk; www.greenvillages.com.au ; www.shareable.net). The term has also been made popular by, among others, Botsman & Rogers (2010) in the 2010 publication "What's mine is yours – the rise of collaborative consumption". But the sharing has not stopped with the sharing of smaller items or possessions. From the hype and buzz of the trend of the collaborative economy and collaborative consumption the term "Collaborative Urbanism" has also emerged. It is based on the same mentality of sharing, openness, and cooperation in order to maximise the use of a given object for increased sustainability, but is contrary to collaborative consumption targeted towards the build environment. It is another form of sharing that also thrives on an internet-based market place (www.nobox-lab.com n.d.; www.streetplans.org n.d.; www.nesta.org.uk n.d.; www.inclusiveurbanism.org n.d.; www.collaborative-urbanism.com n.d.; www.collaborative-urbanism.org n.d.). This *collaborative urbanism* has also along with other trends helped bring a new focus to how we use the limited facilities and resources in our cities; a focus that has also reached the municipalities and space- and property managers at private companies, and forms the inspirational background for the development of the typology presented later in this paper.

Collaborative urbanism can take on many different forms, but it is not necessarily the unique non-duplicable instances that are the most interesting for the municipalities and large property owners who are the focus of this paper. Examples that can serve as inspiration for new ways of organising and optimizing the use of a more general building stock, as the two examples in the following, have the possibility of significantly impacting the use of the existing building stock on a larger scale in cities everywhere.

A small scale example of sharing facilities in a private context is the canteen of the new head office of the Danish engineering firm Ramboll in Copenhagen. As a part of the master plan for the area where the office is located, all buildings need to provide some sort of public facilities. In the case of Ramboll this translated into opening up their canteen to the public. It can be questioned, how much the canteen is actually used by others than the company's staff because of its peripheral location, but the idea was that the company would integrate with its environment. A larger scale example, in a municipal context, is the shared Monaghan Education Campus in Northern Ireland, where an attempt has been made to optimize effectiveness by locating several different schools at the same campus, so for example only one sports facility is needed.

2.2. FM and Shared facilities

At present time, facilities management literature from the field of Space Management provides guides for design of so-called non-territorial office spaces (Becker & Steele (1995); Duffy & Powell (1997)) as well as other shared spaces and facilities within a given organisational and physical setting. However this literature rarely deals with sharing on a broader scale or sharing with actors outside of one's own organization. From literature on Urban Planning (Gehl (1971); Gehl (2010)), as well as Universal Design, (TrinityHaus (2012)) we have guides on the design of public shared urban spaces such as parks and squares, but this literature rarely moves inside buildings. Literature on Community Facilities Management (Alexander (2009); Alexander & Brown (2006)) have begun building a bridge between these two fields, but have so far not moved into the systematic use of shared space between organisations and neither has the field of Urban FM; another new field of study that builds on the work of, among other, Community FM (Roberts (2004); Michell (2013)).

Besides these fields there are a few articles specifically directed at shared space in buildings by for example Yeunsook Lee (Lee et al. (2010)), who focus on interior shared space in apartment buildings, or by Gavan Rafferty (Rafferty (2012)), who introduces a concept for physical shared space in more general terms.

But what is the basic motivation behind the sharing of space? Why should property owners open up their buildings and why should they share their facilities with others? These are multifaceted questions which are difficult to provide *one* ultimate answer to. One big motivator though, could be that we according to the World Health Organization, WHO's, Global Health Observatory (GHO) for the first time have a situation where the majority of the world's population lives in cities. So with more and more people living in cities, space will inevitable become a scarce resource. Sharing facilities that are already present and often stand empty for many hours during the day or week can have many benefits. It is a strategy for a new type of sustainable property management, where the prospective gain of these spaces can be maximised while the use of resources for building new can be minimised. In addition, it can also be a way of creating new contacts by increased interaction with a larger group of people, or an alternative way for a company to practice Corporate-Social Responsibility.

This all sounds good, but in addition to these benefits there are of course also obvious disadvantages and uncertainties involved. Shared use can result in blurred responsibilities or a lack of a ‘sense of ownership’. Furthermore, it may raise questions about costs, security and availability. If for example three schools share one lecture hall, or three companies one lab, this will require rules and agreements on who can use the facility at which times, how users should leave the space when done, and how to share the costs and ownership. A critical FM question would be how to source the facility. Should it be provided by an outside party or become a truly shared ownership?

In this paper, we will not explore the pros and cons of different ways of sharing in more detail; that is for the next phase of the study. For now, we have made an overview (see table 1) based on literature and interviews (Uzairiah et al. (2013); Moss et al. (2009); Rafferty (2012); Fawcett (2009) etc.), illustrating a number of benefits and pitfalls to be studied further in future research.

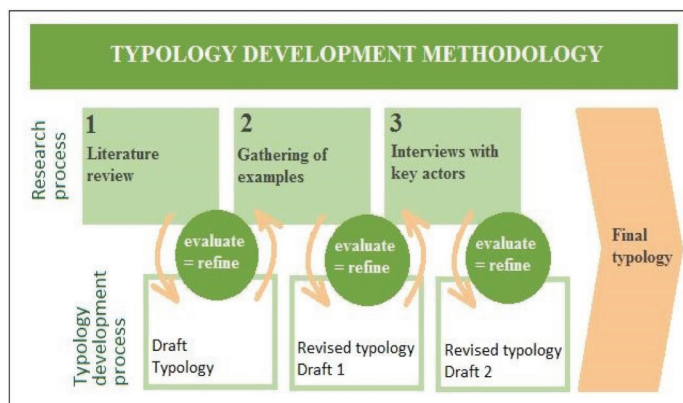
Table 1: Illustration of potential benefits and pitfalls when establishing a shared space

Potential benefits	Potential pitfalls
Sustainability (fewer buildings, optimised use)	More complicated logistics
Synergy (between different users)	Risk of lack of demand
Cost reduction (increasing economies of scale)	Management difficulties due to unclear ownership
Better connection to outside world (CSR)	Less control over availability
Creating a more vibrant atmosphere (avoiding ‘dead space’)	Psychological objections due to feelings of territoriality or privacy
Professional management (in case of third party ownership)	

3. APPROACH

The process used to develop the typology presented in this paper has been divided into three main steps (see figure 1), which will be described in detail in the following.

Figure1: Typology development methodology



1. Gather secondary data via a literature review

A literature review was carried out by use of systematic searches of 64 scientific journals from different databases with use of predetermined keywords, and supplemented by using the references from these first articles to identify additional literature. This resulted in a total of 78 relevant articles, and from these, 12 main articles within the subject were chosen based on relevance to the study as judged by the authors (Fawcett 2009; Rafferty 2012; Moss et al. 2009; Roberts 2004; Uzairiah et al. 2013; Larsen et al. 2011; Wood 2006; Hoffmann et al. 2012; Komarova 2008; Dempsey 1999; Andersen 1985; Michelini & Fiorentino 2012). From this literature, an outline with topics and characteristics of shared space and facilities were developed to guide the search for the examples that should make up the inventory on which the typology is based.

2. Make an inventory of examples

Based on guidance from the outline created in step 1, an inventory of 20 examples was collected through searches of both scientific journals and newspapers in order to secure both scientific well-described examples but also newly identified popular ones. To add to this list of examples a number of industry professionals were asked for input, in order to secure three different sources and an as large variety of examples as possible. An analysis of this inventory showed variations over the same theme and several follow-up analyses' were made focusing on different aspects of the examples, such as type of sharing, reasons behind the sharing, users, suppliers etc. These examples and the knowledge gained during the search were used to revise the outline used to guide the search.

3. Collect primary data from interviews

To gain further and deeper knowledge about the topic of shared space, key actors from selected examples were interviewed. The two examples chosen were Musicon in Roskilde and Lyngby Idraetsby in Lyngby-Taarbæk, since these are both unique and also very complex examples of sharing in a larger network.

Through the entire process, each step was used to evaluate and refine the last, in order to validate and refine the information gathered, as illustrated in figure 1. From the information gathered via this process a table was produced containing short descriptions of all examples concerning different aspects such as users, time of use etc. With this as a base, inductive research was used to produce a set of discriminators based on the questions "What, when, why, who and how" as can be seen in the chapter, "Results – A typology of shared facilities". Based on this information and a final analysis of the inventory of examples with all mentioned iterations taken into consideration, four types were identified, exemplifying the different types of sharing. These types along with the discriminators described above were used to create the typology.

The typology presented in this paper presents four types of sharing facilities, and does not claim to be all comprehensive, but it covers a large variety of shared facilities, from sharing a desk to sharing a building – or a network of such, and describes the characteristics of these different types. It has been developed by looking at the various cases, and only to a small extent by what was found in literature. This is because only one typology of shared space was found in the studied literature (Rafferty (2012)), and this was not found to be relevant to our research. Apparently, the shared use of spaces and facilities is a topic that has not yet received much attention in research.

4. RESULTS – A TYPOLOGY OF SHARED FACILITIES

The typology is focused on the sharing of buildings and on sharing between organizations or businesses that would traditionally prefer exclusive use or ownership ('intra organisational' use). It is sorted by type and scale, meaning that the type of sharing is the decisive factor in the structure of the typology, after which the scale - four different and varying from sharing a desk to a network of buildings, has been used to sort the types from smallest on the left to most comprehensive on the right. A short description of general attributes is linked to each type, along with an illustration to provide a starting point for recognition and discussion, after which the remaining 4 discriminators, "when", "why", "who" and "how" are used to provide the characteristics for each type.

In the following a short description of the four types of sharing identified is presented followed by a description of each of the discriminators, all based on the same systematic approach. It is also important to note that the typology is based on archetypes, and there will therefore be examples and instances that fall in-between some of the categories.

What is being shared - type?

The main discriminator for the typology is as described previously the question of "what" is being shared, which in the typology is illustrated as the "type". This is the basic type of sharing in question and is used to categorise the different forms of sharing into separate groups. Sharing space can take many different forms and is used on many different levels and in many different scales – anything from a shared desk, shared office facilities, shared canteen to sharing a room, a building, a network of buildings or something else entirely.

When is it being shared?

The second discriminator "time" is another important factor when it comes to sharing. Whether it is simultaneous use or serial use of the same space will lead to significant differences regarding possible synergies – or the lack of the same as well as administration, management etc. This makes it very important to determine if it is simultaneous sharing, where different people/organizations use the same space at the same time, or serial sharing where one person/group/organization use the space during some hours of the day and another person/group/organization during other hours of the day.

Why is it being shared?

The specific reasons for sharing can be many, and this is the focus of the third discriminator "Why". It can be considerations regarding costs, increased sustainability by sharing resources, or a hope of creating synergy or agglomeration effects to mention some. Identifying the "why" is therefore an important aspect of determining which type of sharing is most suited to a specific situation or organization, as well as achieving clarity for all partners involved regarding what a given project of sharing is working towards achieving.

Who is sharing?

"Who" is involved in the sharing is the fourth discriminator in the typology. Is the sharing initiated by a public or private organization or institution – or a private individual, what is the owner/user relationship – are the sharing partners equal or not, is the sharing restricted to a specific group, do you need special access, or is the sharing open and free for everyone interested to join. These are all important aspects to have clarified before starting to commit to creating a shared space, and can help focus the search for a specific type of sharing.




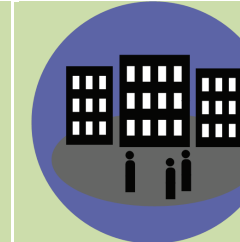
How is it being shared?

How the sharing is being undertaken is the last of the discriminators to be used in this typology of shared spaces, as well as the one that can be the most difficult to describe. There are many different aspects of this specific discriminator, many different ways of organizing it, and it is also this one that seems to possess the most relevance in relation to counselling in regards to the topic of shared space.

4.1. The typology

The process of creating the typology has been a pursuit of diversity and variation, to ensure maximum range and types that would complement each to as high a degree as possible, and they are as mentioned organized by scale from left to right, see Table 2.

Table 2: Typology of shared use of facilities

TYPOLOGY OF SHARED USE OF FACILITIES				
				
Type	Sharing a specific facility – a desk or a workspace in a semi-closed community	Sharing several facilities in an open or semi-closed community	Sharing physical space in a building or a building in itself in a closed community	Sharing facilities between users in a network of buildings/organizations in an open, semi-closed or closed community
General attributes	Sharing is facilitated by an owner and directed towards private individuals	Sharing in the form of a building owner making specific facilities available to the general public	Sharing of space inside a building between different groups or organizations	Sharing of facilities between users of different buildings with different owners
When	Simultaneous use	Simultaneous and serial use	Simultaneous and serial use	Simultaneous and serial use
Why	Keep costs down Synergy	Keep costs down Optimized use CSR activity	Keep costs down Optimized use Surplus space	Keep costs down Optimized use Synergy
Who	Access is restricted to individuals approved by the owner	Access is available to a large group of people in addition to own employees	Access is restricted to pre-agreed groups or individuals decided by the owner	Access is available for employees/residents from the buildings involved
How	One party has ownership of the space, and individuals can gain access either free or for a fee	The organization with ownership opens up specific parts of their property for use for the greater public	One party has ownership of the space and makes it available for specific groups or individuals for a fee	Different building owners come together and agree on sharing specific facilities or buildings instead of each having one
Examples	1) Republikken, DK 2) Plywood sheds, USA 3) School sharing, NED 4) The HUB, DK	5) Lyngby Idraetsby, DK 6) Ramboll, DK 7) Frivilligcenter Hillerød, DK 8) Risskov Library, DK	9) FOF Lyngby, DK 10) Fjaltring-Trans, DK 11) Churches, UK 12) Shared use hubs, AUS 13) Space for entrepren., USA 14) Airport passenger buildings 15) Use of school premises, UK 16) Center for A & E, LTK, DK 17) Denver Shared Spaces, USA	18) Musicon, DK 19) Manchester Media City, UK 20) Shared school campus, NIR

The first type, *sharing a specific facility – desk or workspace*, represents sharing on the smallest scale in the typology. It covers spaces like cowork spaces that specialize in facilitating sharing where you rent a desk – not a specific desk, just a desk – in a shared working space, and also instances where a company invites for example individuals or business partners in, and provides workspace within their company

The second type, *sharing facilities in an open community*, represents the instances where a company or the like makes a part of their facility that would usually only be accessible to individuals inside the organization available for a large group of people, as with the café at Ramboll described earlier. The type can also cover spaces like shared spaces for the community, shared sports facilities etc.

The third type, *sharing physical space in a building*, is sharing of several facilities but within the same building or building complex. This type of sharing can take on many different forms as can also be seen by the examples in the last row of table 2. It is within this type the most significant growth have been observed during this study, and the type that due to the scale and structure is really interesting for businesses and organizations in developing and utilizing their property portfolio.

The fourth and last type, *sharing facilities between users in a network of buildings and organizations*, is the most extensive type of sharing, and the only one that involves more than one building. This type of sharing is often kept within a relatively closed community and often requires a big commitment from the involved parties due to sheer scale.

5. PRACTICAL IMPLICATIONS

Within space management people are already working with shared space situations such as ‘free seating’ offices but this is all kept strictly internal in the organisation. The typology presented in this paper has been made in order to start looking outside the boundaries of a single organisation, a single building or a single use, and instead start to look towards the management of property in general. Shared use of facilities has as a topic a wide societal relevance, but in relation to this paper it has been chosen to address the need of municipalities and other large property owners. This is due to the fact that it is within these types of organisations that a very large part of the building stock not used for private housing can be found, and therefore also here a big difference can be made.

The typology for shared use presented here is meant to support municipalities, property managers and space managers in two different aspects:

- 1) As an analytical tool for investigations of current or future sharing.
- 2) As inspiration and a tool for dialogue when thinking about possibilities for sharing in facilities management in general or specifically for briefing of new building, as well as collaboration when building new.

On a strategic level it can be used for starting a new discussion about property and real-estate management by inspiring the large property owners and municipalities to ask the question: “Do we need to build new or can we maximise the use of what we already have by the facilities? “.

The typology still has its limitations though. It is still a work in progress and needs to be tested and elaborated by looking at more examples. Furthermore, we intend to go deeper into the

pros and cons of the different options. So, at this stage the typology is not final, but more a tool for creating overview and discussions about how to share space in an inter-organisational context. It is a step towards a new strategy for how buildings and facilities can be understood, managed and used for a more optimised use of the built environment.

In relation to sustainability there might in the short term be an increased environmental impact since more people using a building and its facilities for a greater portion of the time will mean an increased use of energy. But when looking on a long term basis and taking the changed use of resources in general as well as for constructing and maintaining new buildings and facilities in to consideration the story might be very different. This paper though, and the typology it presents are not focused on measuring the exact environmental impact of increased use of buildings but instead on creating a foundation for discussing and developing shared use of space in our cities.

6. CONCLUSION

The result of the research undertaken is a first version of a typology of shared use of facilities, which should eventually be able to act as a tool to support municipalities, property managers and space managers in introducing a new way of looking at a more sustainable building portfolio management.

As a part of this typology 4 types of sharing as well as 5 discriminators to describe the sharing have been identified. The 4 types are:

1. Sharing a specific facility – e.g. a desk or a work-space - in a semi-closed community
2. Sharing of several facilities in an open or semi-closed community
3. Sharing physical space in a building or a building in itself in a closed community
4. Sharing facilities between a network of buildings/organisations in a closed community

The five discriminators or variables that have been identified are:

1. What (referring to the object of use)
2. When (referring to the time perspective)
3. Why (referring to the reason behind the sharing)
4. Who (referring to between whom the sharing takes place)
5. How (referring to how the sharing is organised)

The typology is developed with base in 20 distinct examples and therefore covers a wide range of shared spaces but does as mentioned not claim to be fully comprehensive and is not at a final operational stage yet.

Based on this explorative overview, we can conclude that the concept of ‘sharing facilities’ is a relevant topic for facility management with lots of potential benefits in terms of efficiency, innovation and sustainability. It can also be concluded, however, that it is a very general concept that cannot be discussed in depth without asking more detailed questions about what is being shared, by whom and in which way. In this paper, we made a first attempt to unravel these questions and sketch a typology of different ways of sharing.

This means that there is still research to be done into the consequences of shared use of facilities and how these facilities can be managed on a more operational level. With this in mind it can form a solid base for further research into this relatively new subject and open up discussions regarding alternative ways of maximising the use of the limited resources in our cities, and help explore if *the shared portfolio* can be a way of planning our cities in line with the fast growing trend of the shared economy.

AKNOWLEDGEMENTS

As a part of the study behind this paper, a number of people in different organisations have provided valuable insights into the subject, and the typology would not have been possible to develop to the stage it is at now without this assistance. Many thanks are extended to:

City of Knowledge Secretariat, Lyngby-Taarbæk, Denmark

The Musicon Secretariat, Roskilde, Denmark

Københavns Ejendomme, København Denmark

Center for Arealer og Ejendomme, Lyngby-Taarbæk, Denmark

Center for Sundhed og Kultur, Lyngby-Taarbæk, Denmark

REFERENCES

- Alexander, K., 2009. Community based facilities management.
- Alexander, K. & Brown, M., 2006. Community-based facilities management. *Facilities*, 24(7/8), pp.250–268. Available at: <http://www.emeraldinsight.com/10.1108/02632770610666116> [Accessed November 11, 2012].
- Andersen, H.S., 1985. Danish low-rise housing co-operatives (bofællesskaber) as an example of a local community organization. *Scandinavian Housing and Planning Research*, 2(2).
- Becker, F.D. & Steele, F., 1995. *Workplace by design: mapping the high performance workspace*, Jossey-Bass Publishers.
- Botsman, R. & Rogers, R., 2010. *What's mine is yours*,
- Dempsey, L., 1999. The network and the library: working in a new shared space: infrastructure and institutions.pdf. *The Electronic Library*, 17(4).
- Duffy, F. & Powell, K., 1997. *The new office*, Conran Octopus.
- Fawcett, W.H., 2009. Optimum capacity of shared accommodation: yield management analysis. *Facilities*, 27(9/10), pp.339–356. Available at: <http://www.emeraldinsight.com/10.1108/02632770910969595> [Accessed February 13, 2013].
- Gehl, J., 2010. *Cities for people*,
- Gehl, J., 1971. *Life between buildings - using public space*,
- Hoffmann, B. et al., 2012. *Kreative Miljøer – mellem faciliteter og facilitering*,
- Komarova, M., 2008. Shared Space in Belfast and the Limits of A Shared Future. , (3), p.28.
- Larsen, J.L. et al., 2011. Urbanising facilities management: the challenges in a creative age. *Facilities*, 29(1/2), pp.80–92. Available at: <http://www.emeraldinsight.com/10.1108/02632771111101340> [Accessed December 5, 2012].
- Lee, Y., Kim, H. & Yoon, H., 2010. Spatial Representation of Community Shared Spaces Preferred by Residents. *Indoor and Built Environment*, 19(1), pp.163–174. Available at: <http://ibe.sagepub.com/cgi/doi/10.1177/1420326X09358023> [Accessed January 8, 2013].
- Michellini, L. & Fiorentino, D., 2012. New business models for creating shared value. *Social Responsibility Journal*, 8(4), pp.561–577.
- Michell, K., 2013. Urban facilities management: a means to the attainment of sustainable cities? *Journal of Facilities Management*, (3), pp.22–23.
- Moss, Q.Z., Ruzinskaite, J. & Alexander, K., 2009. Using buildings for community benefits: A best practice case study with North City Library. *Journal of Retail and Leisure Property*,

- 8(2), pp.91–98. Available at: <http://www.palgrave-journals.com/doi/10.1057/rfp.2009.2> [Accessed February 4, 2013].
- Owyang, J., Tran, C. & Silva, C., 2013. *The Collaborative Economy*,
 Rafferty, G., 2012. Embracing the Creation of Shared Space: Considering the Potential Intersection between Community Planning and Peace-building. *Space and Polity*, 16, p.18.
- Roberts, P., 2004. FM: new urban and community alignments. *Facilities*, 22(13/14), pp.349–352. Available at: <http://www.emeraldinsight.com/10.1108/02632770410563059> [Accessed November 9, 2012].
- Rosenberg, T., 2013. It's Not Just Nice to Share, It's the Future. *The New York Times*, pp.4–7.
- Silver, J., 2013. The sharing economy: a whole new way of living. *The Observer*, pp.1–8.
- TrinityHaus, 2012. *Shared Space, Shared Surfaces and Home Zones from a Universal Design Approach for the Urban Environment in Ireland - executive summary*,
 Uzairiah, S. et al., 2013. Social enterprise applications in an urban facilities management setting. *Facilities*, 31(5).
- Voight, J., 2013. Enabling the sharing economy. *Adweek*, pp.3–7.
- Wood, B., 2006. The role of existing buildings in the sustainability agenda. *Facilities*, 24(1/2), pp.61–67. Available at: <http://www.emeraldinsight.com/10.1108/02632770610639206> [Accessed May 2, 2013].
- www.collaborativeconsumption.com, Collaborative consumption. Available at: <http://www.collaborativeconsumption.com/> [Accessed September 6, 2013].
- www.collaborative-urbanism.com, Collaborative urbanism. Available at: www.collaborative-urbanism.com/ [Accessed September 6, 2013].
- www.collaborative-urbanism.org, Collaborative urbanism. Available at: www.collaborative-urbanism.org/ [Accessed September 6, 2013].
- www.denstoredanske.dk, Andelsbolig. Available at: http://www.denstoredanske.dk/Mad_og_bolig/Bolig/Boligforhold/andelsbolig?highlight=andelsbolig [Accessed September 2, 2013].
- www.greenvillages.com.au, Collaborative consumption. Available at: <http://www.greenvillages.com.au/our-top-collaborative-consumption-sites/> [Accessed September 6, 2013].
- www.inclusiveurbanism.org, Collaborative urbanism. Available at: <http://www.inclusiveurbanism.org/about-ciu.html> [Accessed September 6, 2013].
- www.nesta.org.uk, Collaborative consumption. Available at: http://www.nesta.org.uk/news_and_features/collaborative_consumption [Accessed September 6, 2013].
- www.nobox-lab.com, Collaborative urbanism. Available at: <http://www.nobox-lab.com/villes-sans-limite/?lang=en> [Accessed September 6, 2013].
- www.shareable.net, Collaborative consumption. Available at: <http://www.shareable.net/news/economy/collaborative-consumption> [Accessed September 6, 2013].
- www.streetplans.org, Collaborative urbanism. Available at: <http://www.streetplans.org/> [Accessed September 6, 2013].
- www.thesharehood.org, Collaborative consumption. Available at: <http://www.thesharehood.org/> [Accessed September 6, 2013].

CHAPTER 5

BUILDING CONDITION AND EVALUATION

5.1

The Office Users' Experience of Mixed-mode Systems: Behavioural Thermoregulation

Angela Alessi, Christopher Heywood and Scott Drake

5.2

A Rating System for Buildings Condition Ranking

Mario Claudio Dejaco, Fulvio Re Cecconi and Sebastiano Maltese

5.3

Questionnaire Design for Objective Evaluation of Performance of Built Facilities

Gopikrishnan Seshadhri and Dr VM Topkar

5.1

THE OFFICE USERS' EXPERIENCE OF MIXED-MODE SYSTEMS: BEHAVIOURAL THERMOREGULATION

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ABSTRACT

Purpose: The main research purpose of this study was to understand thermoregulatory behaviour in a mixed-mode environment. How people would use their thermoregulatory behaviour to achieve better comfort and satisfaction?

Background (State of the Art): Traditionally thermal comfort is established by measuring air temperature, humidity, air velocity, clothing and activity. However, other factors related to people's thermoregulatory behaviour (such as opening and closing windows or switching the thermostat from HVAC to natural ventilation) that lead occupants to a better sense of thermal comfort and satisfaction should be considered.

Approach (Theory/Methodology): The case study for this research was the National Australia Bank (NAB), Melbourne Docklands with a mixed-mode north façade designed with multifunctional spaces in which people could choose between air-conditioning and natural ventilation. The adaptive theory of thermal comfort was adopted with thermal (instruments in the study space), perceptual (two surveys in spring and autumn) and behavioral investigations (one week of observations for each season).

Results: The results showed that occupants felt comfortable in the NAB mixed-mode space in autumn and spring with a high level of acceptability of the thermal environment throughout the year. Despite being highly site specific, the research highlighted the benefits of a mixed-mode system in an air-conditioned office and the importance of occupants' behavioural thermoregulation in raising their sense of comfort and satisfaction.

Practical implications: Thermoregulatory behaviours are central in office environments and are better exercised in spaces that allow occupants to interact with their environment. Therefore such spaces should be included in the design of office buildings.

Originality: At present this is the only thermal behavioural study conducted in a multifunctional mixed-mode space within an air-conditioned office. It demonstrated that a well-designed mixed-mode space provides a high level of occupant comfort and satisfaction.

Keywords: Adaptive thermal comfort, Mixed-mode systems, Office design, Users' control, Post Occupancy Evaluation.

1 INTRODUCTION

Modern office buildings are traditionally associated with non-operable windows where HVAC systems use heating, ventilation and cooling to create a constant uniform climate. However, recently concerns for improving environmental performance in buildings have led to the integration of natural ventilation creating mixed-mode systems that allow occupants to choose between air-conditioning and natural ventilation. While air-conditioning conforms to steady state conditions of thermal comfort based on the heat-balance theory and the Fanger's PMV-PPD model, the mixed-mode allows variations associated with external climate to improve indoor air-quality and thermal comfort. In this perspective people's adaptive thermal behaviour is central and affects the thermal environment. This person-centred approach is embedded in the adaptive thermal comfort theory where variable thermal conditions are considered, highlighting the role of occupants (Brager and de Dear, 1998). Studies (Baker & Standeven, 1996, Humphreys & Nicol, 1998, Rowe, 2004) have confirmed the benefits of greater environmental variations within buildings, either via users' adjustment to windows, shading devices or by adjusting the HVAC set points to prevailing outdoor temperatures. While the heat-balance theory considered people as passive recipients of the thermal environment, for the adaptive thermal comfort theory people become active participants that affect the environment.

Behavioural thermoregulation's core strategy of the adaptive thermal comfort theory resides in what is called 'users' control'. Users and their experience are also central to the modern 'club office' (Duffy, 1999) where interaction, collaboration and communication are paramount. The evolution of the office space developed from paper-based factories to become information technology spaces and now they are the meeting point of socializing knowledge networks. The office space evolved from a Taylorist regular approach of order, hierarchy and supervision to the contemporary office village where multi-functionality, informality and even relaxation are conducive to enhancing work performance. Office design has an important role that changed with new ways of conceiving workplaces where being an occupant assumed very different connotations. From busy clerks to more demanding computer-based managers, occupants would now like to control their work and the office environment (Duffy, 1999, Leaman & Bordass, 2000, Laing, 2006) bringing a dynamic element into both the office environment and its thermal comfort.

This research is a contribution to the adaptive thermal comfort theory and focuses on a field-work study at the National Australia Bank (NAB), Melbourne, Docklands, investigating thermal behaviours of office users in a multifunctional space. The NAB building has been designed with the north façade as kitchen-lounges where occupants can work, relax or have meetings. These spaces have mixed-mode systems that allow people to switch from air-conditioning to natural ventilation. The research aim was to understand not only the thermal conditions of the occupants in the mixed-mode kitchen-lounge but also the behavioural ad-

justments people perform in it in order to achieve comfort and satisfaction with the space and the thermal environment.

2 STATE OF THE ART/BACKGROUND

Thermal comfort in office buildings is currently established by the American Society of Heating Refrigerating and Air-Conditioning Engineers, ASHRAE Standard 55 for which air temperature and radiation temperature should be 23.8 °C, humidity at 50%, air velocity <0.20 m/s with clothing insulation between 0.5 and 1 Clo and metabolic heat at an average of 1 Met (ASHRAE, 2004). This standard is the result of the heat-balance theory and almost a century of thermal comfort research in climate chambers, dominated by engineers such as P.O. Fanger, for which thermal comfort is achieved through four physiological factors related to the environment (temperature, humidity, air velocity and radiation) and two components associated with people (clothing insulation and activity level). For Fanger, a satisfying thermal condition was achieved when the subjects of his chamber experiments reached 'neutrality' (Fanger, 1970). This neutral point was established through standardized questionnaires assuming that a given thermal environment's effects are mediated exclusively by the physics of heat and mass exchanges between body and environment. The ASHRAE Standard 55 represents a very efficient response to thermal comfort however, a symptom that starts as a physiological need to feel warm or cold also results in almost automatic, unconscious behavioural responses like taking a jacket off, seeking a cool place and relaxing when external temperatures are high, or simply drinking some water, or engaging in some activity when the temperature is low. These changes in the environment represent a major impact on people's thermal comfort and account for metabolic activities only in part. Instead they are a very important way in which people adapt to the environment, they interact with it establishing what de Dear defines as 'perceptual relativity' (de Dear, 2009), the core idea of adaptive thermal comfort theory.

From previous research it was noted that there is a discrepancy between people's expectations and the actual thermal environment they encounter (Humphreys & Nicol, 1998 & 2002; Leaman, 2002, 2004 & 2006b; Brager & Baker, 2008 & 2009; de Dear, 2009 & 2010). In particular, the heat-balance theory with its PMV index is very different from occupants' reported thermal sensations (Brager et al, 1994; Oseland, 1995; de Dear et al, 1997; de Dear, 2004) and induces unnecessary cooling and heating (Oseland & Humphreys, 1994; Brager & de Dear, 1998 & 2000). In addition, for naturally ventilated buildings, the indoor temperature has been correlated to the monthly average outdoor temperature that induces adaptive actions in the occupants (Humphreys & Nicol, 1970; de Dear & Brager, 2002; de Dear 2009). Furthermore, thermal expectations play a central role in occupants' satisfaction and create the possibility for a wider range of acceptability of the thermal environment (Baker, 1996; de Dear et al, 1997; de Dear 2009). This is particularly true for naturally ventilated spaces and it also happens in mixed-mode buildings where people could switch from the HVAC system to natural ventilation

The assumption that thermal uniformity of the heat-balance model is a necessity has been challenged by numerous authors (Heschong, 1979; Brager et al, 1994; Kwok, 2000; de Dear, 2004; Leaman, 2004) on the basis that people are predisposed to avoid steady state conditions such as those provided by the HVAC environments. Kwok (2000, p.2) advanced the idea as 'thermal boredom'. The issue becomes the person-environment system, where the human

element is a malleable construct that includes social, cultural and psychological paradigms in a holistic view and physiology is only one aspect to consider (Chappells & Shove, 2004).

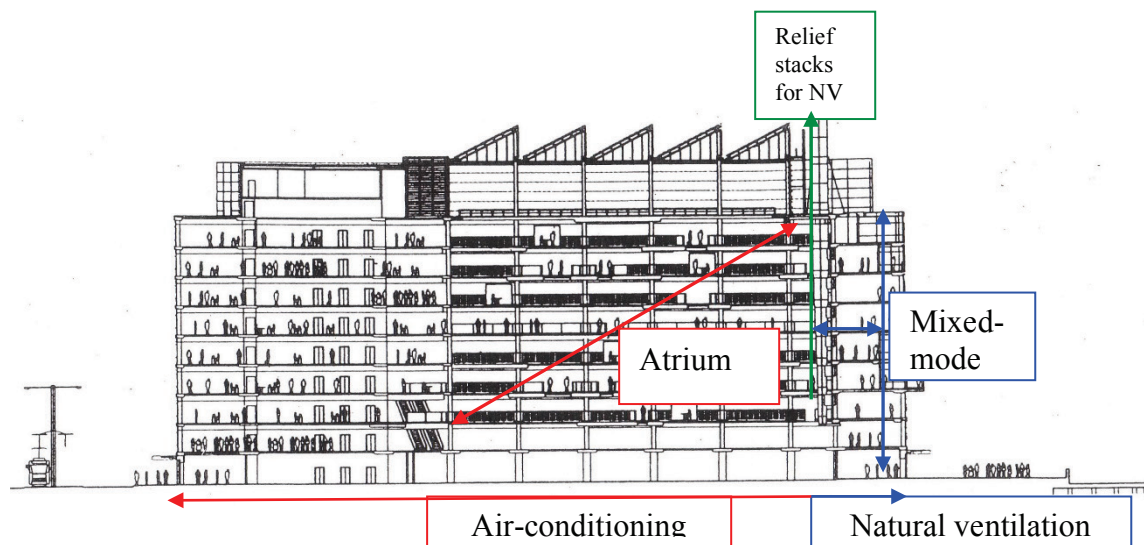
Standard 55 considers 80% of occupants satisfied as a reasonable threshold for a thermally comfortable environment where a room's thermal comfort will not satisfy all people but should satisfy the great majority. However, dissatisfaction in office environments where people complain about the thermal conditions is very high (Leaman & Bordass, 2000) being up to 75% of complaints in commercial buildings about temperature, draught, noise, or the lack of control over the environment by its occupants especially in air-conditioned office buildings (Brager & Baker, 2008; International Facility Management Association-IFMA, 2009). Brager and Baker's (2008) study showed that only 11% of the 370 buildings studied, most of which had air-conditioning systems, met the 80% ASHRAE comfort standard. The solution to thermal comfort problems is said to be providing people with individual direct control features such as access to thermostats, operable windows, and under-floor air distribution with adjustable grilles (de Dear, 2004; Leaman, 2009; Drake et al, 2009; Deuble et al, 2010). Comfort becomes an experience where the personal factors are not only the clothing insulation and metabolic heat specified in Standard 55 but people variously adapting including, for example, opening a window, changing thermal conditions, to avoid the rigid constant states that characterize Fanger's model.

Ideally, today office buildings and workplaces should be designed for collaborative and flexible teams where a combination of air-conditioning and natural ventilation guarantee occupants the climatic control over their environment as well as the mobility that the knowledge worker needs. However, the majority of office buildings have not changed their design very much with the HVAC system still providing steady thermal states for a non-Tayloristic work environment. This study argues that the dynamic component of people that could create effective office spaces is also an important component to creating satisfying thermal comfort situations. This research is not in the laboratory but the field where the researchers observe people in their everyday environment, while occupants are reacting to their surroundings, adapting and changing them. The thermoregulatory behaviours that people can exercise in a mixed-mode space by choosing between air-conditioning and natural ventilation or by opening or closing windows or in any other way would be a key factor to improve thermal comfort and satisfaction in office environments. This study is a contribution to the adaptive thermal comfort theory and, at present, the only one conducted in a multifunctional mixed-mode space within an air-conditioned office.

3 APPROACH/METHODOLOGY

The National Australia Bank (NAB), case study for this research is one of Australia's largest commercial buildings, equivalent to a typical fifty storey building turned on one side. Its 'ground-scraper' structure makes it a low building that is very different from the typical city skyscraper. The open plan offers flexible workplaces rather than locked up offices and represents an alternative to traditional offices that reflects the new way workplaces around the world are being designed (Figure 1). The NAB employs 3900 people with 45% female and 55% male (the NAB workplace manager). The level 6 building 2 where the surveys were conducted accommodates 240 desks divided in two piers of 120 each. The percentage of employees sitting at the desk is around 50% of the availability of the space, as indicated by the NAB workplace manager.

Figure 1: NAB cross section (drawing courtesy of Mr John Hurren, NAB Facility Manager)



The NAB building is an open plan air-conditioned office that includes a mixed-mode system in kitchen-lounges throughout its north façade where occupants can choose to switch from air-conditioning to natural ventilation. These spaces were conceived as places to which people could move, make decisions and feel connected to both air and light. The air-conditioned area of the office spaces is kept at an average temperature of about 22.5°C and at an average humidity level of about 50%, as per ASHRAE recommendations. The mixed-mode area has operable windows as part of the natural ventilation control strategy. Pressing an ‘open’ or ‘closed’ switch, opens or closes a window pair at the same time emitting an audible warning signal. The system is locked out if weather conditions are not conducive to windows’ operations but they can be opened when wind speed is lower than 12 m/s, when no rain is detected, when no fire alarm is present, and the outside temperature is between 19.0 °C and 27.0 °C.

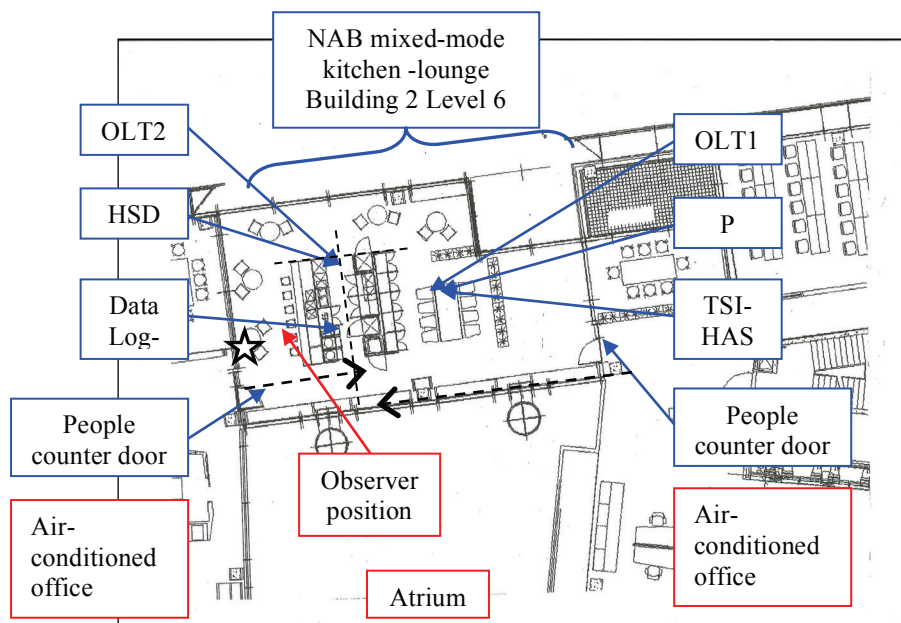
Thermal behaviour is complex involving both objectively measurable factors such as temperature and humidity and also subjective aspects such as individual responses, perceptions and feelings. While it is possible to research thermal comfort eliminating subjective variables within a controlled laboratory environment, it is also important to conduct field work where these other variables must be taken into account as was done in this study. The investigation considered not only the traditional thermal conditions of the NAB mixed-mode kitchen-lounge but also the behavioural adjustments occupants performed to enhance their comfort and satisfaction of the space and its thermal environment. This study used thermal, perceptual and behavioural approaches simultaneously. First, as in traditional thermal comfort studies, direct measurements were taken in the space to monitor traditional thermal comfort parameters such as temperature, humidity and air velocity. Indoor climatic data was collected through instruments positioned in the kitchen-lounge while outdoor climatic data was obtained from the Bureau of Meteorology and compared to the indoor thermal data. Second, two surveys in autumn and spring, the two seasons when outdoor and indoor climatic conditions were thought to be more conducive to behavioural adaptations such as switching from air-conditioning to natural ventilation, were conducted to understand people’s preferences in the mixed-mode kitchen-lounge. Third, behavioural data was obtained through repetitive observations, one week in each season of the year of investigation, from March 2009 to March 2010.

In February 2009 a set of instruments and a data logger were set up in the NAB mixed-mode kitchen-lounge of Building 2 Level 6 (Figure 2). The instruments positioned in the space were as follows:

1. Omega linear thermistor (OLT)1 to measure temperature and mean radiant temperature;
2. Omega linear thermistor (OLT) 2 to measure mean radiant temperature;
3. Hygrometer-hycal solid device (HSD) to measure relative humidity;
4. Pyranometer (P) for radiation; and
5. TSI heated sphere anemometer (TSI-HAS) for air velocity.

These instruments were connected to the data logger positioned at the top of the cabinet at the centre of the mixed-mode kitchen-lounge (Figure 2).

Figure 2: The NAB mixed-mode kitchen-lounge: instruments and observer location



Two surveys were conducted in autumn and spring when it was thought that the mixed-mode system could be turned more easily to natural ventilation and people could open the windows. It was expected that during winter and summer the HVAC system would be activated, being most probably the outdoor temperature below 19 °C or above 27 °C. The autumn survey took place on the 29th April 2009 and the spring survey occurred on the 10th November 2009 with 30 people¹⁰ volunteering in both surveys between 10.00 am and 3.00 pm. They both took place in the NAB mixed-mode kitchen-lounge of Building 2 Level 6. The surveys' questions aimed to understand occupants' acceptability and control of the indoor climatic conditions when the mixed-mode space was naturally ventilated. Initial questions were focused on un-

¹⁰ The people counter positioned in the kitchen-lounge calculated an average of 1581 entrances to the space per season. Considering that there are 260 working days in one year, and 65 in one season, 24 to 25 people entered the NAB mixed-mode space on an average per day. Therefore, the 30 NAB people volunteering for the surveys represent a statistical relevant number considering the daily users of the mixed-mode kitchen-lounge.

derstanding participants' personal characteristics and thermal sensations such as their age, their gender, their clothing level, how they felt in the mixed-mode space, and if there was any change to be made in the air-movement. In order to understand adaptive thermal strategies put in place by NAB occupants in the mixed-mode kitchen-lounge, questions about the space, the reasons why and when people entered that space and what they liked about it or if any adjustment was needed to be made in order for them to feel satisfied were also asked in the surveys. The questionnaires were developed in accordance with de Dear & Brager's (1998) ASHRAE system RP-884 database. Questions using the seven points ASHRAE scale (of cold, cool, slightly cool, neutral, slightly warm, warm and hot) were given to establish the acceptability, the preferences and the desires of occupants' for their thermal environment.

Four weeks of observations were conducted one in each season of the year of investigation, from March 2009 to March 2010 for a total of 200 hours. Considering that the kitchen-lounge was designed as informal environment where work was also possible the observer's behaviour was consistent with the space usage (the position of the unobtrusive researcher conducting this study is indicated in Figure 2). While sitting at that table, notes about people's behaviour were taken, together with habits, clothing levels and various activities. Unsolicited comments were also received from NAB occupants.

NAB occupants thermoregulatory behaviour was expected to relate to the function of the space, mainly a kitchen, and therefore activities like drinking and eating were anticipated. Other forms of thermoregulatory behaviour were also expected such as occupants turning the system from HVAC to natural ventilation or vice-versa. These behaviours were observed but also investigated through the surveys and are an essential aspect of this study's results.

4 RESULTS

The results consider outdoor and indoor climatic conditions and people responses in the surveys, but also the observations, in order to understand occupants' thermal sensations, acceptability and specific thermoregulatory behaviours in the NAB mixed-mode space.

Climatic results

Outdoor and indoor data analysis showed that the mixed-mode system could have been utilized in the NAB kitchen-lounge for 31.6% of the working days during the study period. While winter was run on HVAC most of the time, both spring and autumn could have given occupants the choice of natural ventilation for one third of the time during each of those seasons. Furthermore, beyond expectation, during summer the NAB mixed-mode could also have been utilized in its natural ventilation mode for more than half of the working days during that season. Overall, occupants could have exercised their thermoregulatory behaviours in the NAB mixed-mode space for one third of the working days during the entire year.

Survey results

The mixed-mode thermal environment of the NAB kitchen lounge was determined on one side by the outdoor climatic conditions and on the other it was influenced by the air-conditioning system of the office, becoming part of the air-conditioned office when HVAC mode was in place. On the day of both surveys the mixed-mode system switched automatically to HVAC conditions because of the cold weather in the first survey (in Autumn) and the hot weather in the second survey (in Spring). In this situation people could not open the windows and from the results of the survey the majority of them didn't try to do

so, on this or any other day. In Autumn while the outdoors was very cold, the indoor average temperature in the mixed-mode space was almost 25 °C (Fig.3), being almost 2 degrees warmer than the air-conditioned office space, for which people should have felt comfortable. In Spring while the outdoors was very hot, the indoor average temperature in the mixed-mode space was about 23 °C (Fig. 4) and in the same way people should have felt comfortable. However, in both surveys when people were asked how they felt in the room, a considerable amount of them said they were cool and they would have liked the mixed-mode to be warmer. Despite this, respondents said there was no need for change in the mixed-mode space and the temperature for the majority of people was 'OK if not perfect'. The results of the autumn and spring surveys indicated that NAB occupants' thermal sensations in the mixed-mode kitchen-lounge were acceptable for the majority of people in both surveys with no need to change, despite the mixed-mode being in HVAC mode due to the outdoor climatic conditions. In Autumn respondents discomfort at 25 °C could be explained by the fact that people were influenced by the outdoor climatic conditions of the day when the temperature had started getting cooler but the ground was still warm from the previous days, therefore the perception of the outside temperature made them register the cold. On the other hand in Spring respondents discomfort at 23 °C when outside was very hot could be explained in a similar way, considering that the temperature had started getting hotter but the ground was still cold. Furthermore the cold registered by the respondents in Spring could be related also to people's expectation and the actual thermal environment they encountered, with the HVAC system inducing unnecessary cooling. The physical and visual connection, that NAB occupants felt in the mixed-mode space with the outdoor environment influence their level of acceptability of the mixed-mode environment. The satisfaction was determined by other factors related to the mixed-mode space.

Figure 3: Climatic conditions of NAB mixed-mode space during the first survey on the 29th April 2009

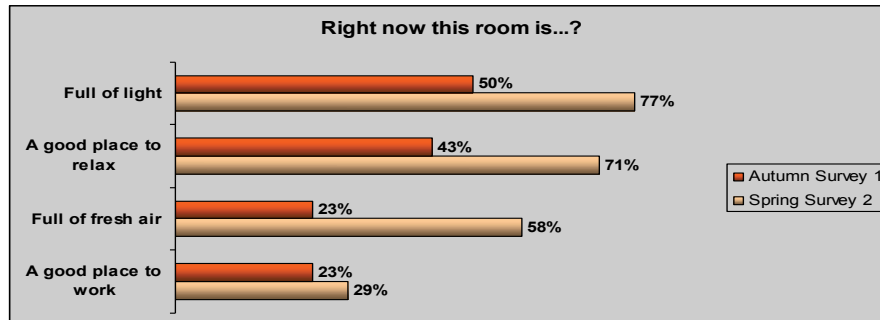
Outdoor conditions	NAB mixed-mode kitchen lounge	Air-conditioned office
Temperature (average) 12.27°C	Temperature (average) 24.74 °C	Temperature (average) 22.6°C
Humidity (average) 66.5%	Humidity (average) 29.85%	Humidity (average) 40%
Wind speed (average) 24 Km/h (6.65 m/s)	Air velocity (average) 0.013 m/s	Air velocity Not available

Figure 4: Climatic conditions of NAB mixed-mode space during the second survey on the 10th November 2009

Outdoor conditions	NAB mixed-mode kitchen lounge	Air-conditioned office
Temperature (average) 34.56 °C	Temperature (average) 23.03 °C	Temperature (average) 22.6°C
Humidity (average) 35%	Humidity (average) 49.05%	Humidity (average) 40%
Wind speed (average) 24 km/h (96.65 m/s)	Air velocity (average) 0.021 m/s	Air velocity Not available

Behavioural results - People's behaviour was investigated by asking NAB occupants to describe the space, what they were doing in it, when they entered and what they liked about it. In both surveys most participants described the kitchen-lounge as being full of light and a good place to relax, and also a place full of fresh air. The latter is an important result considering that windows could not be opened due to the outdoor temperatures and the HVAC system's operation system (Figure 5). Therefore, this result is related to the possibility of opening the windows in the mixed-mode space, highlighting this perceptual characteristic of thermal comfort.

Figure 5: Survey 1 and survey 2, The most important characteristics of the room



The view and the fresh air were also very important reasons why people chose to enter the mixed-mode space together with feeling relaxed. People related strongly to the concept of fresh air. In fact, this concept described the space for 23% of them in the autumn survey and 58% of people in the spring one. It was one of the reasons of what people were doing in the mixed-mode space, especially in spring (13%) (Figure 6). In both surveys, it was also what 33% (autumn survey) and 52% (spring survey) of occupants liked when they were in the mixed-mode space (Figure 7). While it is not possible to say that NAB residents entered the space to actually breathe fresh air (other than 3% and 13% respectively shown in Figure 6) it could be said that this was one of very important characteristics that people indicated of the mixed-mode kitchen-lounge. However, relaxation, light and the view represented other very important aspects of the space that people appreciated and that contributed to their feeling of comfort.

Figure 6: Survey 1 and survey 2, Occupants' activities

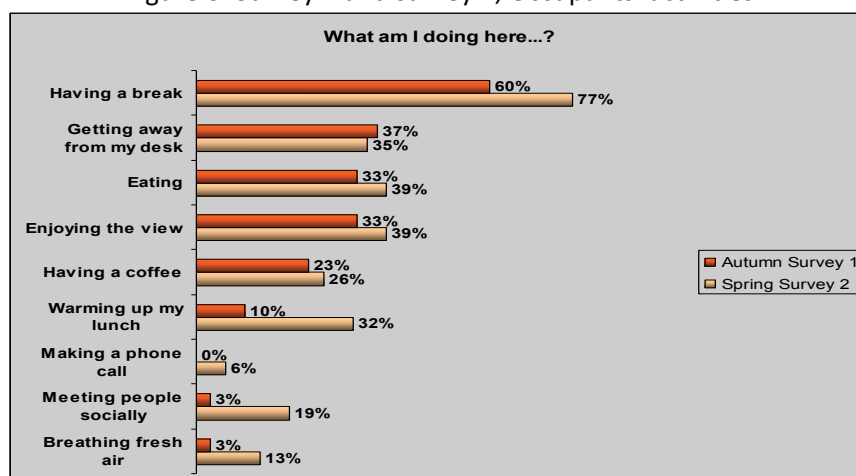
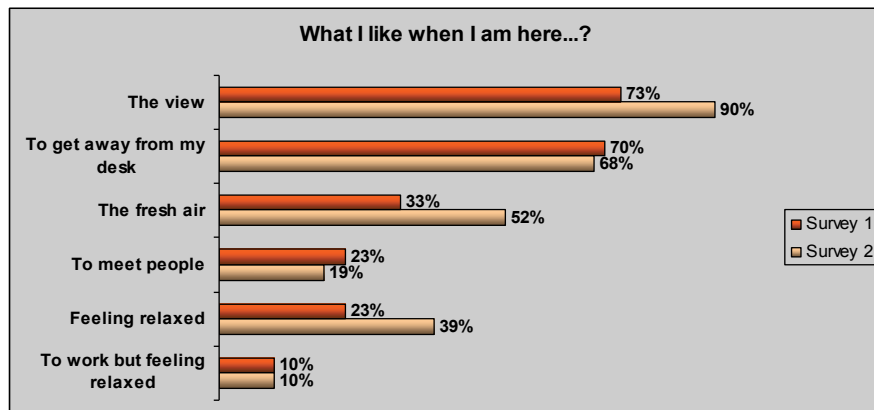


Figure 7: Survey 1 and survey 2, Occupants' preferences



Observations showed that people behaved almost the same throughout the four seasons and this was related primarily to the function of the space which was a kitchen. Occupants entered the space to eat, especially at lunch time, but also for breakfast, and to drink either water or hot drinks several times during the day. It was apparent that these activities were conducted with an underlying desire of relaxation that was emphasized in the surveys as an important aspect of what people liked about the mixed-mode space. It was observed that occupants invested a long time in preparing the food they were eating, in preparing hot drinks they were drinking and in the related cleaning and washing of glasses and plates. The view was seen to be one of the most important uses of the mixed-mode space confirming what emerged in the surveys. While on one hand the kitchen was seen to offer occupants an opportunity for readily identifiable relaxing activities, on the other hand it was conducive to other behaviours, such as filling glasses of water without drinking them, washing the same glass several times, taking food in and out of the fridge without a precise strategy for preparing or eating it, filling and emptying water bottles with a logic that was not related to drinking or cleaning the object, and drying kitchen utensils that were already dry. These actions were not rare and showed a latent desire for something that was beyond the actions themselves. Furthermore, another similar behaviour was seen many times during the day: people would enter the kitchen-lounge for a stroll, they would come in, reach the kitchen bench, stop there, look at the view, turn around and go out. This particular behaviour was designated as the 'zum-zum walk' and could indicate the need for relaxation and having a break but it also pointed at the fact that people chose to enter the mixed-mode space to have that moment and that could be considered as part of their thermoregulatory behaviour. For this reason the space and its characteristics are very important. The mixed-mode kitchen-lounge was a destination of choice that could ensure people physical and emotional comfort by looking at the view or just perceiving fresh air despite the fact that during both surveys the outdoor climatic conditions did not allow the opening of the windows. Nevertheless occupants rated that possibility as one of the most important of their thermoregulatory behaviours.

In conclusion, people came in the NAB mixed-mode kitchen-lounge for many reasons, but most importantly they entered the space to indulge in thermoregulatory behaviours underlined by a desire to get away from their desk, have a break and refresh by enjoying the view and the fresh air, even if only perceived. For this reason they also appeared to enter the kitchen-lounge without a specific reason just for a 'zum-zum walk'. The NAB mixed-mode space was so much more than just a kitchen-lounge. It was a space where people's adaptive oppor-

tunities could be exercised, though rarely so, or even just perceived and for this reason their sense of comfort was satisfied.

5 PRACTICAL IMPLICATIONS

The results indicated that NAB occupants' thermal sensations in the mixed-mode kitchen-lounge were acceptable for the majority of people with no need to change, despite the mixed-mode being in HVAC mode due to the outdoor climatic conditions. The physical and visual connection that NAB occupants felt in the mixed-mode space with the outdoor environment influenced their perception of fresh air, indicative of the psychological aspect of thermal comfort. The level of acceptability of the mixed-mode space was also related to other aspects of the environment such as the view and the sense of relaxation, two characteristics that add once more to the perceptual idea of comfort and satisfaction. The zum-zum walk was observed to be an interesting aspect of NAB occupants interaction with the mixed-mode space and relevant for their sense of relaxation and overall comfort. All these aspects determine important design features for the mixed-mode space and should be included in the design of modern office buildings.

6 CONCLUSION

In conclusion, this study gives an important insight in adaptive thermal comfort research for mixed-mode spaces showing that people's thermoregulatory behaviour includes psychological aspects as well as physical ones. Furthermore, this research showed the importance of a space such as the NAB mixed-mode kitchen-lounge in air-conditioned offices where people can go to have a break, they go to breathe fresh air (even if only perceived) and they enjoy the view connecting to the outdoor climatic conditions as part of their thermoregulatory behaviour. Designing mixed-mode multifunctional spaces as part of modern office will offer occupants the opportunity to raise their sense of satisfaction of the thermal environment. At present this is the only study to have occurred in a multifunctional mixed-mode kitchen-lounge within an air-conditioned office. It demonstrates that a mixed-mode multifunctional space is an important aspect of modern office design and its thermal environment.

REFERENCES

- Baker, N and Standeven, M (1996), "Thermal comfort for the running buildings", *Energy & Buildings*, n.23, pp.175-182.
- Brager, G, and Baker, L (2008), 'Occupant Satisfaction in Mixed-Mode Buildings', *Proceedings of Conference Air Conditioning and the Low Carbon Cooling Challenge*, Windsor, UK, 27-29 July (URL:http://www.cbe.berkeley.edu/research/pdf_files/Brager2008-OccSatisfaction-MM.pdf) [Accessed: March 2010].
- Brager, G and de Dear, R (1998), "Thermal adaptation in the built environment: a literature review", *Energy & Buildings*, n.27(1), pp.83-96.
- Brager, G, Fountain, M, Benton, CC, Arens, EA, and Bauman, FS (1994), 'A Comparison of Methods for Assessing Thermal Sensations and Acceptability in the Field', in *Thermal Comfort: Past, Present and Future*, NA, Oseland, and MS Humphreys (eds), Building Research Energy (BRE), London, pp.17-38.

- Chappells, H, and Shove, E (2004), 'Comfort: A Review of Philosophies and Paradigms', March, (URL: http://www.lancs.ac.uk/fass/projects/futcom/fc_litfinal1.pdf) [Accessed: October 2010].
- de Dear, R (2009), 'Thermal Comfort in Natural Ventilation- a Neurophysiological Hypothesis', *43rd Annual Conference of the Architectural Science Association, ANZAScA 2009*, University of Tasmania, pp.1-6.
- de Dear, R (2004), 'Thermal Comfort in Practice', *Indoor Air*, n.14, suppl.7, pp.32-39.
- de Dear, R, and Brager, G (2002), 'Thermal Comfort in Naturally Ventilated Buildings: Revisions to ASHRAE Standard 55', *Energy and Buildings*, n.34, pp.549-561.
- de Dear, R, and Brager, G (1998), 'Thermal Adaptation in the Built Environment: a Literature Review', *Energy and Buildings*, n.27, p.83-96.
- Deuble, M, and de Dear, R (2010), 'Green Occupants for Green Buildings: the Missing Link?', *Proceedings of Conference, Adapting to Change: New Thinking on Comfort*, Windsor, Network for Comfort and Energy Use in Buildings, London, pp.21-27
- Drake, S, de Dear, R, Alessi, A, and Deuble, M (2009), 'Occupant Comfort in Naturally Ventilated and Mixed-Mode Spaces within Air-Conditioned Offices', *Proceedings of the Australia and New Zealand Architectural Science Association (ANZAScA) 43rd Annual Conference Performative Ecologies in the Built Environment. Sustainable Research across Disciplines*, November 25/27, School of Architecture & Design, University of Tasmania, Launceston, pp.267-284.
- Duffy, F (1999), *The New Office*, second edition, Conran Octopus, London.
- Fanger, PO (1970), *Thermal Comfort*, Danish Technical Press, Copenhagen.
- Herschong, L (1979), *Thermal Delight in Architecture*, MIT Press, Cambridge, Massachusetts, London, England.
- Humphrey, M and Nicol, J (1998), "Understanding the adaptive approach to thermal comfort, *ASHRAE Transactions*, n.104(1), pp.991-1004.
- Kwok, AG (2000), 'Thermal Boredom', *Proceedings Passive and Low Energy Architecture (PLEA)*, July, Cambridge, England, (URL: <http://darkwing.uoregon.edu/~akwok/pdfs/Boredom.pdf>) [Accessed: June 2008].
- International Facility Management Association (IFMA) (2009), 'Behind the Lines of Temperature Wars', *International Facility Management Association (IFMA) Surveys Facility Pros (sic)*, August, (URL: <http://hvac.com/air-conditioning/behind-lines-temperature-wars-0809/>) [Accessed: March 2010].
- Laing, A (2006), "New patterns of work: the design of the office", in *Reinventing the Workplace*, J, Worthington (ed), second edition, Elsevier, Amsterdam, pp. 29-49.
- Leaman, A (2009), 'The Great Escape. Understanding why People are Desperate to Flee Buildings', *Ecolibrium*, June, vol.8-5, p.18-20.
- Leaman, A (2004), 'Outside the Comfort Zone: Buildings and Basic Human Needs', *Human Givens Journal*, vol.11, n.2, pp.34-35.
- Leaman, A and Bordass, B (2000), "Keep occupants satisfied", *Energy & Environmental Management*, II quarter, pp.21-27.
- Rowe, D (2004), "Thermal comfort in a naturally ventilated environment with supplementary cooling and heating", *Architectural Science Review*, n.47(2), pp.131-140.

5.2

A RATING SYSTEM FOR BUILDING CONDITION RANKING

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ABSTRACT

Purpose: Do people know everything about their asset? The aim of this work is to give to building process stakeholders some Key Performance Indicators (KPIs) able to help them during the decision process, which characterises operation, maintenance and repair phases. These KPIs are intended to be included inside a rating system developed by the authors.

Background: There are many different types of evaluation techniques, from empirical to theoretical and from internal to external; most of the assessment techniques found in literature can be categorised among them. Others described some methods, different for objectives and measuring parameters: qualitative evaluation criteria, cost-driven KPIs and physical state ones in combination with standards and regulation compliance. Rating system can be implemented in Building Condition Assessment.

Approach: This work highlighted the necessity of mainly two types of KPIs: one (technical index) to assess building condition in terms of aging and anomalies of its components; the other (documents index) to describe the quality and quantity of available building documents taking into account legal requirements. In addition to these indexes, a set of standardised repair alternatives has been defined.

Results: Output of this system is the current asset situation picture, with indication of missing documents, serious anomalies and interventions needed to restore required performances. Three layouts (synthetic, by technological units, detailed) are targeted to different users' categories.

Practical implications: This research is focused on building rating and maintenance operations selection. Future development will study benchmarks for economic, law compliance and environmental assessment.

Originality: The originality of this work stays in the possibility of quickly evaluating an asset, obtaining a list of criticalities, to be connected with major works, ready to be scheduled and performed.

Keywords: Building Condition Assessment, Key Performance Indicator, Maintenance, Document, Degradation

1 INTRODUCTION

Purpose of this research is to give to buildings stakeholders a rating system able to ease the decision process during refurbishment, handover, operation and maintenance management. This tool should be used for evaluating a single building (giving the current situation picture) and for comparing buildings inside an asset, helping in setting priorities.

This research, starting from other works and clear necessities, like the ones noted by Baird et al. (1996) and by Johnston, McFallan and Tilley (2002), wants to give a practical solution to a true problem of the facility management field and can be categorised as an empirical research.

Nowadays asset managers' decisions are becoming more complicated and a deep knowledge of the asset condition is needed, as noted by Flores-Colen, De Brito and Freitas (2010), and this, unfortunately, is not always available. Typically, asset managers must take decisions about maintenance and renewal alternatives based on sparse data about the current state of their own assets, as noted by Wittchen and Brandt (2002), and this often causes waste of money. Same problems can also be found at building handover when facility managers typically receive many "bankers' boxes" full of information about their facilities. Today those who use information provided must, at best, pay to have the data keyed into the relevant data systems. At worst, facility maintenance contractors are paid to survey the existing building to capture as-built conditions, as noted by Gallaher et al. (2004). The lack of information, therefore, causes more or less directly a series of other problems, which lead to the use of unsafe buildings, i.e. buildings that do not comply with basic law requirements, to unsatisfactory buildings, with poor performances, and to low yield investments. This lack of information can be solved by Building Condition Assessment (BCA), which can be applied to an asset with different levels of depth and accuracy.

The research is targeted to all the stakeholders that have to deal with constructed assets and the connected lack of information: owners, asset managers, tenants and professionals. Different users with different backgrounds; for them, three outputs have been developed.

2 STATE OF THE ART

In these paragraphs the state of the art of BCA techniques and maintenance operations databases, used as starting point for this work, is reported, with the intention of highlighting most critical points to be solved.

2.1 Building Condition Assessment

BCA techniques have been studied since the birth of the necessity of understanding, what are current asset performances, to consequently act in the most effective way.

Assessment methods can vary also according to the building scale that they want to evaluate: from general to particular, where each component has a specific and detailed evaluation

method, like the one explained by Rodrigues, Teixeira, and Cardoso (2011) for façades evaluation.

Building evaluation techniques are conducted in combination with other important activities, like inspections and maintenance operations planning. Inspections, which cause overcosts if not efficiently organised, must be planned considering what is the subject of the inspection itself, as noted by Uzarski, Grussing and Clayton (2007). Maintenance operations, in terms of both schedule and costs, must be planned consequently to BCA, to be the most effective as possible, as noted by Percy and Kobbacy (2000).

In these last years energy/sustainability-oriented refurbishments became more and more important, so BCA is also oriented to support this kind of refurbishment; this can be done, as written by Menassa (2011) and Caccavelli and Genre (2000), by linking to the assessment an analysis of the main criticalities and potentials. These topics are obviously related to facilities management, on which Shohet and Lavy (2004) showed possible improvements.

TOBUS and EPIQR projects demonstrate that evaluation techniques, to be more effective, should be targeted to building function, as instance tertiary or residential as noted by Allehaux and Tessier (2002) and Brandt and Rasmussen (2002).

Last but not least, evaluation techniques should give as output an index/rate/mark, as noted by Roulet et al. (2002) and Salim and Zahari (2011), to ease decision makers' work and to create a building ranking inside the asset to prioritise maintenance works and evaluate refurbishment scenarios.

The requirements analysis of building evaluation techniques shown the extreme difficulty in achieving a detailed survey with a small effort. Two possible solutions, which are a good compromises between a detailed survey and a quick one, are: a) a quick survey on the whole building to rate and compare it with other buildings of the same asset and b) a slower survey, more detailed and applied on a small buildings group, also focusing mainly on more deteriorated components, with a rate associated.

2.2 Maintenance operations

After BCA, maintenance management is fundamental for correct building operation: many strategies can be used (condition-based, preventive, periodic, etc. – no need to write here well-known definitions, as defined in the UNI EN 13306:2010 and by Molinari (2002)) but the main aims are always two: to achieve a defined acceptability level with the lowest economic effort or to maximise building condition with a finite amount of money.

Starting from these considerations, many solutions can be adopted, alone or combined, to achieve the desired maintenance level: main operations scheduled and minor ones done when a failure occurs, only preventive maintenance, no maintenance until failure, to use a global service approach and so on. In addition to these, for an asset object of survey, an incremental approach can be adopted, combining above-mentioned techniques: “urgent” interventions to restore main features and then “standard” operations, scheduled according to a maintenance plan, connected to a budget allocation over many years. Decisions can be supported by instruments and tools, like the one described by Vanier et al. (2006) and by Shohet (2003).

Not depending on assets type, extension and even age, maintenance managers (professionals, building managers, global services, etc.) have to deal with the problem of defining maintenance

nance operations in terms of types, frequencies and costs. In doing this, assistance comes from databases, as the one made by Marcon and Re Cecconi (2012) and Perret (2001), and connected software, more or less complex, detailed, scalable and targeted to one or more building functions but, at the end, containing an interventions list. These databases are meant to be used both to extract/adapt/duplicate/etc. operations to be organised in an external software and to create directly the maintenance plan. By the way, users, to fit the maintenance plan to their building, have to take in account its specificity (exposition, function, users, etc.).

Plants maintenance, generally speaking, is more advanced than building components one, as can be seen in ASHRAE (2013), mainly because its standardisation: gathering data from similar components, making statistics and knowing with enough precision components durability (i.e. working hours) is easier; this is not so easy for a wall, whose behaviour is influenced by lots of parameters hardly verifiable (with low economic and time effort).

What maintenance management for construction components requires is a level of accuracy comparable to the plants one. This can be achieved also by sharing knowledge on components maintenance operations, faults and behaviours, maybe linking them to BIM objects, to easily share data and to create more accurate statistics.

3 APPROACH

This research, started with the analysis of many BCA techniques, wants to improve the state of the art by the implementation of some KPIs. The idea of creating a rating system for BCA was born together with the necessity to create and manage a well-organized building logbook, which allows stakeholders (owners, users, professionals, etc.) to get a better and faster analysis of the building itself. This work highlighted the necessity of mainly two types of rates: one (technical index) to assess the building condition in terms of aging and anomalies of its components; the other (documents index) to describe the quality and quantity of available building documents taking into account legal requirements. Eventually, an operations list helps in maintenance management.

3.1 Technical index

The technical index is used to assess building condition, by measuring building components degradation and service life. This index is made by three sub-indexes: the first two comparing the actual service life of each component with its reference one (called service life indexes) and the third one evaluating anomalies found on each building component (called degradation index). Since the technical index of a building is a function of the indexes of its components, a standard Work Breakdown Structure (WBS) has been created. This WBS, following UNI 8290:1981 standard, has been organised through five levels, from general to detailed: 1) class of technological units; 2) technological units; 3) class of technological elements; 4) technological elements and 5) elements materials.

The index is calculated for both technological elements (i.e. building components) and technological units; the other three levels are just useful for organization and comprehension of the WBS itself. The different importance of each WBS component has been taken into account calculating two different series of weights: the first related to the economic value and the second related to the criticality of each component. Both weights have been calculated and applied at the technological units level (level 2). The economic weight is proportional to the percentage contribution of each technological unit to the total construction cost. A pair

comparison method (Analytical Hierarchy Process – AHP) has been used to assess the relative importance of each technological unit then converted into criticality weight. The AHP has been used only as an instrument to define weights and its use is not part of the research.

Another instrument needed for the computation of the technical index is a Reference Service Life (RSL) database that has been built starting from a literary review of major existing databases and from experts' interviews.

A list (and a classification) of all possible anomalies for each component is another necessary element for the calculation of the technical index. First of all, building components anomalies have been classified, according to the magnitude of their damages on the component itself, in low, medium and serious. Anomalies are also classified according to the typology: step change (on/off) and gradual change, with evaluation of the extension (low, medium-low, medium-high, high). Each anomaly has a univocal code, a name, a description and a measuring parameter. The complete list is made by totally 431 anomalies.

Each building component can be evaluated using a diagnostic form, which consists of four parts: a) form data (code, name, number); b) component data (code, name, notes, ASL – Actual Service Life); c) anomalies check list (with the possibility to select the anomalies for the component and, if need be, to put the extension) and d) indexes output (automatically calculated as soon as the data are entered). Totally 438 forms, one per each possible building component, have been created. These forms are collected in 18 folders, which are the WBS 18 technological units.

The two service life indexes are alternative, D^+ for components with $ASL \leq RSL$ (1) and D^- for components with $ASL > RSL$ (2). Once the service life indexes for each component are known the same indexes can be computed for the upper level of the WBS (3) (4). The last step consists in the evaluation of the service life indexes for the entire building by performing a weighted average of the technological units indexes using weights described above (5) (6).

On the other hand, the degradation index consists of three equations (7) (8) (9) at the component level, allowing the calculation of the low/medium/serious anomalies. These three partial indexes have to be aggregated in one, describing the component situation, through a weighted average (10). The next step, as for service life indexes, is the calculation of the index at the technological unit level (12), which uses the same weights and equations of the service life indexes.

The necessity of having a single index for building technical rating is clear: with a single number a ranking can be done among more buildings and also decision-making becomes easier, avoiding possible misunderstanding. The technical index is the comparison between the selected building and an optimal one, without anomalies and maintained properly, but with the same age of the real building. So the first step is to calculate the area of the two triangles, as shown in Figure 3 (left), and to make the ratio between the two values (13).

The graph of Figure 3 (left) shows two triangles: a) dashed line: the best situation in which the building can be. No anomalies ($A = 100\%$), all the components have been replaced according to their RSL ($D^- = 100\%$). D^+ represent the age of the building, which physiologically gets older. This triangle is the best results that the building can get and b) continuous line: this is the current building situation. Index A decreases when anomalies are found and D^-

decreases when one or more components pass RSL limit. D^+ is always equal to the dashed one because, as said before, ageing is physiological.

The more the continuous line is smaller than the dashed one, the more the building has a low degradation index, which means the presence of anomalies and components that do not fully satisfy their requested performances. This graph does not substitute the analytic calculation but it is a good way to show results in a more comprehensive (for a non-technician) way than just a number. As can be seen in next paragraphs, this graph is always associated to analytical results, split by building (Figure 6) technological units (Figure 4) and even components, if need be, depending on the user.

Figure 1: Technical index formulas

$$\begin{aligned}
 D_C^+ &= \frac{RSL - ASL}{RSL} & (1) \quad D_{Bld}^- &= \frac{\sum_{k=1}^o D_{TU,k}^+ * W_k^{E/C}}{\sum_{k=1}^o W_k^{E/C}} & (6) \quad A_{TU} &= \frac{\sum_{i=1}^q A_{C,i}}{q} & (11) \\
 D_C^- &= 1 - \frac{ASL - RSL}{ASL} & (2) \quad A_L &= \frac{\sum_{i=1}^L P_{L,i} * E_i}{L} & (7) \quad A_{Bld} &= \frac{\sum_{k=1}^o A_{TU,k} * W_k^{E/C}}{\sum_{k=1}^o W_k^{E/C}} & (12) \\
 D_{TU}^+ &= \begin{cases} \frac{\sum_{i=1}^n D_{C,i}^+}{i} & \text{if } n \geq 1 \\ 0 & \text{if } n = 0 \end{cases} & (3) \quad A_M &= \frac{\sum_{j=1}^M P_{M,j} * E_j}{M} & (8) \quad I_{Tech} &= \frac{Area_{Building}}{Area_{Optimal}} [\%] & (13) \\
 D_{TU}^- &= \begin{cases} \frac{\sum_{j=1}^m D_{C,j}^-}{j} & \text{if } m \geq 1 \\ 1 & \text{if } m = 0 \end{cases} & (4) \quad A_S &= \frac{\sum_{k=1}^S P_{S,k} * E_k}{S} & (9) \\
 D_{Bld}^+ &= \frac{\sum_{k=1}^o D_{TU,k}^+ * W_k^{E/C}}{\sum_{k=1}^o W_k^{E/C}} & (5) \quad A_C &= \frac{A_L * W_L + A_M * W_M + A_S * W_S}{(W_L + W_M + W_S)} & (10)
 \end{aligned}$$

3.2 Documents index

Documents index is organised as a weighted ratio between the number of available documents and the number of documents that should be available for the specific building. This ratio involves weights able to consider the different importance of all documents related to building design, construction and operation. A list of required documents is the starting point for the documents state evaluation: in this research nine documents families have been created to classify each document, needed either by law or by standard practice. Documents families have been weighted with the AHP pair comparison system to get their relative importance.

Some categories may be not necessary for a specific building (i.e. in Italy not every building needs fire safety documentation), so, depending on the actual number of families, weights are recalibrated. In addition to these weights, documents inside each family are organized in four categories according to their importance, with an associated weight: a) Level 1: compulsory documents, which the absence implies illegal or unsafe building use; b) Level 2: compulsory documents, which the absence does not imply illegal building use; c) Level 3: important documents, not required by law and d) Level 4: (non-exhaustive) list of documents with just explanatory purpose.

The calculation of the documents index starts with the evaluation of each document score, obtained multiplying importance weight and presence (14), which is 1 if the document is available and 0 if not. Documents index can also take in account multiple documents of the same type, if need be. The family documents score is the ratio (17) between the sum of all the available documents (15), divided by the sum of all the necessary documents (16). Eventually, building documents index calculation is done by simply summing (19) the weighted in-

dexes of each family (18). The result is a number between 0 and 1, where 1 is the best case, all needed documents are available and 0 the worst, where no document is available.

Results can be summarised in a Kiviat graph, as in Figure 3 (right), with two different series of data: a) dashed line: these scores correspond to the minimum level of mandatory documents (level 1) that the building must have. Not all the nine categories must necessarily have mandatory documents and b) continuous line: this line joins all the building scores for the nine documents families. A score higher than the red limit does not mean a sufficient score, which is given by the sum of all the documents of level 1 that the building requires.

These two graphs summarize in a synthetic view the data showed respectively in Figure 3 4 and in Figure 5. The left graph contains just the three final technical indexes (calculated with the data of the technological units in Figure 4) while the right one contains the weighted score of the analysed documents families (gathered from Figure 5). The “complete view” (graphs + tables) allows users in easily detecting building criticalities and potentials.

Figure 2: Documents index formulas

$$S_{doc} = presence * importance \quad (14) \quad S_{max} = \sum_{i=1}^n S_{doc,i}^{necessary} \quad (16) \quad I_{family} = S_{family} * W_{family} [\%] \quad (18)$$

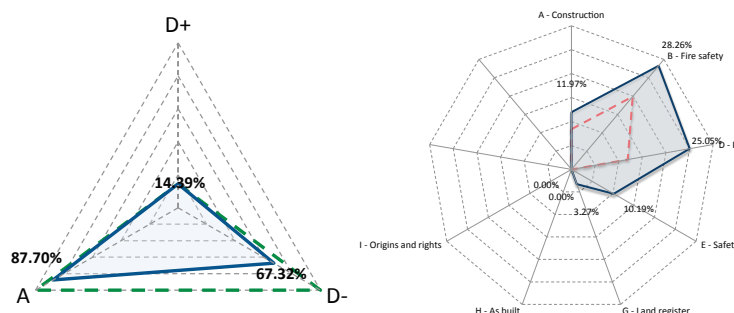
$$S_{eff} = \sum_{i=1}^n S_{doc,i} \quad (15) \quad S_{family} = \frac{S_{eff}}{S_{max}} * 100 [\%] \quad (17) \quad I_{Doc} = \sum_{i=1}^N I_{family,i} [\%] \quad (19)$$

3.3 Building index

The last problem concerning the condition assessment of a building is the aggregation of the final indexes. The question is: is one index better than two or three or four ones? Many options could be evaluated: a) 4 different efficiency indexes (documents, 2 service life, 1 degradation); b) 3 different efficiency indexes (documents, service life, degradation); c) 2 different efficiency indexes (documents and technical) and d) 1 efficiency index (collecting all the previous).

The main problems are the information lost during the calculation and not the aggregation (which is only a mathematical problem): for an inexperienced user one index can be simpler than four ones but the information given by a single index could be misunderstood without an appropriate explanation (such as a detailed report). Using a simple average seemed to be the best way to have a single result without losing information, comparable with others and always associated with a graphical output, as outlined in bar chart of Figure. This double view (graph and analytic data) is useful because it can represent both the indexes and their average but also just one of them, if need be, for a partial evaluation.

Figure 3: Technical (left) and Documents (right) index graphical output



3.4 Urgent maintenance operations

The second step to be done, after BCA, is to associate “problems” encountered (anomalies, missing documents) to possible solutions. Building components can be associated to maintenance interventions, split in: a) preventive maintenance; b) condition-based maintenance and c) urgent interventions. The complete set of intervention can be seen as the component maintenance profile. This work is focused on urgent interventions, studied appositely to solve above-mentioned anomalies. Urgent interventions are the ones not supposed to be scheduled upon a long time, but necessary to restore lost performances and acceptability conditions (depending also on the anomalies gravity and extension, they have urgency level). Nevertheless, they need a schedule, to be grouped together (opportunity maintenance) and evaluated in terms of effort, for both time and costs.

These operations, in this first step, are associated just to components and not to spaces and/or to technological units; this will be for sure a research development. The same for legal requirements compliance: maintenance can be done to restore problems due to standards update and/or non-compliance with existing laws (i.e. parapets lower than a certain height, fire safety doors too deteriorated to comply with their fire resistance, boilers not well connected with chimneys, etc.).

Urgent operations, to be effective, have been divided in macro-categories, not depending on the component: a) complete replacement; b) partial replacement; c) restoration and d) cleaning.

After this, operations have been listed for each single component anomaly, with a one (anomaly) to lots (operations) connection. Obviously it is always true that one intervention can solve more than one anomaly; in this case operations have been duplicated. Eventually each anomaly has at least one intervention. They have been also associated, depending on anomaly criticality, to a qualitative schedule: short, middle and long term. In addition, operations, to be more detailed, have been defined and component-targeted as much as possible, avoiding general interventions of “restoration” or similar. At the end, each operation is characterised by name, description and it will be associated also, in a short future, with a unitary cost. Complete component maintenance profile will contain frequencies (by ranges) and unitary costs.

Urgent maintenance operations come out directly from a database, by checking the presence/absence of each single component anomaly. Then they have to be organised and grouped together depending on client necessities. This last part cannot be automatized because it is strictly dependent on the building under analysis, its policy, function, users and anomalies localisation.

4 RESULTS

Results can be better explained with a case study application: a residential 5-storeys above ground building (construction year 1950) in Milan has been assessed through this system and KPIs have been used to estimate main interventions to be done in a short-middle-long term. This case study has been previously used during the test phase but in this proceeding has only the purpose of clarify and demonstrate the developed method.

First of all a quick survey of building common parts (external, internal, basement) has been performed and some photos have been taken; then data (32 components split in 9 technologi-

cal units) have been re-elaborated to collect indexes at components-technological units-building level. In addition to this, documents presence/absence has been evaluated to obtain the documents index. Eventually building index has been computed as the average of the previous two.

System automatically gives to the user an operations list, split in short-middle-long term (according to anomalies criticality); then the user has to set priorities and manage (select-deselect) interventions to define the operations to be done. This is fundamental because no software can decide what is the right choice instead of the user, which decides according to building policies, economic situation, damages extension and localisation.

Here main results are reported and commented.

4.1 KPIs for BCA

System starts with single components analysis (formulas 1-2-7-8-9-10) and then automatically gives outputs at technological units (formulas 3-4-11) and building level (formulas 5-6-12). In this case study one diagnostic form for each component has been filled, up to 32 elements analysed. In any case, a more detailed assessment is allowed with this tool, as instance one form for each storey/apartment/façade, depending on needs. Results are summarised in Figure 4 (left) and also outlined in Figure 3 (left).

The ratio (13) between the two triangles of Figure 3 (left) gives an output equal to 63.17%, which means that some components passed their RSL and many others need to be replaced, because too much deteriorated. Grey line means that the technological unit has not been assessed.

Figure 4: Technical index summary

TECHNOLOGICAL UNIT			WEIGHTS	WEIGHTED INDEXES			ANOMALIES
#	CODE	NAME		D ⁺	D ⁻	A	# A
01	S.F	Foundations					0 on 0
02	S.C	Retains structures					0 on 0
03	S.E	Elevation struvtures					0 on 0
04	C.V.O	Opaque envelope	5	20.41%	2.72%	13.27%	22 on 90
05	C.V.T	Transparent envelope	8	12.12%	1.26%	6.06%	44 on 105
06	C.O.I	Slab on ground	1	3.83%	0.00%	1.92%	3 on 13
07	C.OSA	Slab on open spaces					0 on 0
08	C.S	Roof					0 on 0
09	PI.V	Invernal vertical partition	5	22.49%	0.00%	13.87%	26 on 52
10	PI.O	Invernal horizontal partition	4	16.89%	0.00%	11.96%	9 on 66
11	PE.V	External vertical partition	1	2.18%	0.00%	1.99%	7 on 20
12	PE.O	External horizontal partition	2	4.77%	0.00%	2.18%	17 on 27
13	IFS.IC	HVAC					0 on 0
14	IFS.IDS	Water and sanitary plant					0 on 0
15	IFS.E	Electric plant	4	13.58%	10.41%	13.58%	3 on 22
16	IFS.SL	Sewer plant					0 on 0
17	IFS.TR	Lift plant	2	3.73%	0.00%	2.49%	2 on 12
18	IFS.A	Fire plant					0 on 0
TOTAL		32	100.00%	14.39%	67.32%	87.70%	133 on 407

Documents index has been evaluated starting from a pre-formatted documents checklist that gave positive results, as shown in Figure 5 and outlined in Figure 3 (right).

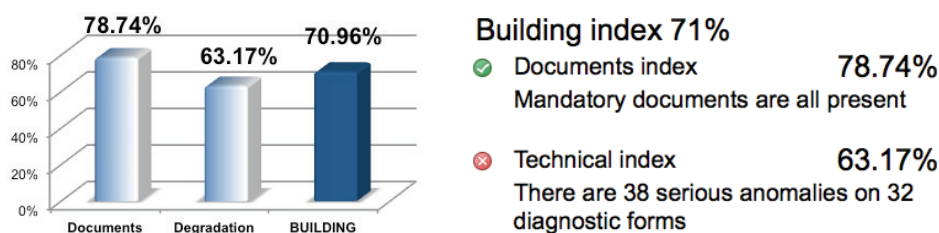
Documents index, given by the sum of weighted scores (19), is equal to 78.74%. Green “checks” show that no mandatory documents are missing; no as built documents have been found, although they are important. The building was built before Italian law on structures safety and urban planning, so no document is required.

Figure 5: Documents index summary

DOCS FAMILY		WEIGHT	FAMILY SCORE [%]	WEIGHTED SCORE [%]
A - Construction	✓	11.97%	100.00%	11.97%
B - Fire safety	✓	28.26%	100.00%	28.26%
C - Structures	✓			
D - Plants	✓	25.05%	100.00%	25.05%
E - Safety and maintenance	✓	10.19%	100.00%	10.19%
F - Urban planning	✓			
G - Land register	✓	3.27%	100.00%	3.27%
H - As built	✓	18.22%	0.00%	0.00%
I - Origins and rights	✓	3.05%	0.00%	0.00%

Eventually these KPIs can be summed up to achieve a single KPI describing the whole building situation, as shown in Figure 6. This last view gives to the user some key information: documents situation is under control, just some useful (but not mandatory) documents are missing; technical part, on the contrary, shows many problems: more than half of the components have serious anomalies, to be solved as soon as possible. This is the starting point for maintenance operations selection and planning. It can be considered a building healthy state, but authors deliberately did not fix a sufficiency level because this system must be adapted to really different building categories and functions; only two indicators (mandatory documents lack and serious anomalies presence) are considered important, with the results, to understand in a quick view the building current state.

Figure 6: Building index summary



4.2 Planned maintenance

Building current situation is now known, so maintenance operations can be evaluated according to anomalies encountered (133 totally – 16 serious, 41 medium, 83 minor) to solve criticalities. System automatically gives operations with a qualitative priority (short-middle-long term) according to damages gravity, but the user has to define, for each component, either to act or not and, if yes, what is the intervention that best fits his needs. A short extract of operations list for wooden windows is reported in Tabel 1

Table 1: Maintenance operation extract – wooden windows

NAME	OPERATION	SCHEDULE	DESCRIPTION
Finishing degradation	Restoration	long-term	Repainting and/or replacing hardware parts
Superficial deposits	Cleaning	long-term	Use of specific instruments and products
Hardware degradation	Restoration	middle-term	To be fixed, oiled and tuned
Gasket degradation	Partial replacement	middle-term	Disassembly and replacement
Biological attack	Restoration	short-term	Biological colony removal
Missing parts	Partial replacement	short-term	Disassembly and replacement

In this case, user can decide either to partially restore these windows or, since they passed their RSL, to completely replace them. These interventions are out of the context, which is known only by the maintenance manager, and they have to be grouped together: as instance restoring the whole façade seems to be useful, instead of replacing first the windows and few years later the plaster and/or the finishing.

Now the user of this system has all the information necessary to organise operations budget and schedule, according to his policy. Further step will include definition of unitary prices for operations and of the complete component maintenance profile.

5 PRACTICAL IMPLICATIONS

This system, as written in the approach adopted, is focused on BCA, with the aim of giving an answer to facility management true problems: filling the lack of information connected to an asset and then organising the most urgent operations, needed to restore actual problems, in addition to the standard maintenance plan, if present.

KPIs have been studied with the objective of being a support for different users categories, from owners and tenants, to professionals, building managers and construction companies. Different views (synthetic, detailed, by component) can satisfy different needs: handover, refurbishment, market value estimation and also maintenance budget allocation.

This instrument is also a valid guide during concept and design phases, i.e. documents index can be used as checklist, diagnostic forms and maintenance operations list can be the starting point for the maintenance plan definition.

6 CONCLUSION

This research started with the objective of giving to asset stakeholders a complete set of KPIs to easily manage their daily problems. BCA KPIs have been tested with various case studies, as written by Dejaco, Re Cecconi and Maltese (2013), and now attention is focused on maintenance KPIs, to develop indicators able to help users during OM&R management. These benchmarks can be easily connected to component maintenance profile, providing to stakeholders analytic data about the future building situation.

The complete system will be connected with the economic part (interventions and also building operation cost) and with energetic simplified assessments, starting point for refurbishment alternatives evaluation, but also for the definition of the asset true market value (or the effort needed to restore it).

ACKNOWLEDGEMENTS

The authors greatly acknowledge Fondazione Opificio and the Italian Association CNPI (Consiglio Nazionale dei Periti Industriali) for funding this research.

REFERENCES

- Allehaux, D. and Tessier, P. (2002), "Evaluation of the functional obsolescence of building services in European office buildings", *Energy and Buildings*, 34, 2, 127-133.
- ASHRAE (2013), "Service Life and Maintenance Cost Database", available at: <http://xp20.ashrae.org/publicdatabase/> (accessed 20 November 2013).
- Baird, G., Gray, J., Isaacs, N., Kernohan, D. and McIndoe, G. (1996), *Building evaluation techniques*, McGraw-Hill, New York.
- Brandt, E. and Rasmussen, M.H. (2002), "Assessment of building conditions", *Energy and Buildings*, 34, 2, 121-125.
- Caccavelli, D. and Genre, J.-L. (2000), "Diagnosis of the degradation state of building and cost evaluation of induced refurbishment works", *Energy and Buildings*, 31, 2, 159-165.
- Dejaco, M. C., Re Cecconi, F., Maltese, S. (2013), "Logbook's dynamic structure in building process", in *39th World Congress on Housing Science – IAHS*, Milan, 447-454.
- Ente Italiano di Unificazione, UNI 8290 (1981), *Edilizia residenziale – Sistema tecnologico – Classificazione e terminologia*.
- Ente Italiano di Unificazione, UNI EN 13306 (2010), *Maintenance – Maintenance terminology*.
- Flores-Colen, I., de Brito, J. and Freitas, V. (2010), "Discussion of Criteria for Prioritization of Predictive Maintenance of Building Façades: Survey of 30 Experts", *Performance of Constructed Facilities*, 24, 4, 337-344.
- Gallagher, M.P., O'Connor, A.C., Dettbarn Jr, J.L. and Gilday, L.T. (2004), "Cost analysis of inadequate interoperability in the US capital facilities industry", *NIST Publication GCR 04-867*.
- Johnston, D.R., McFallan, S.L. and Tilley, P.A. (2002), "Implementation of a property standard index", *Facilities*, 20, 3/4, 136-144.
- Marcon, F., Re Cecconi, F. (2012), *Manutenzione e durata degli edifici e degli impianti*, Maggioli Editore, Rimini – Italia.
- Menassa, C.C. (2011), "Evaluating sustainable retrofits in existing buildings under uncertainty", *Energy and Buildings*, 43, 12, 3576-3583.
- Molinari, C. (2002), *Procedimenti e metodi della manutenzione edilizia – Vol. I – La manutenzione come requisiti di progetto*, Sistemi Editoriali, Caloria – Italia.
- Percy, D.F. and Kobbacy, K.A. (2000), "Determining economical maintenance intervals", *International Journal of Production Economics*, 67, 1, 87-94.
- Perret, J. (2001), *Guida alla manutenzione degli edifici*, Hoepli.
- Re Cecconi, F., Dejaco, M. C., Maltese, S. (2013), Efficiency Indexes for Building Condition Assessment, in *39th World Congress on Housing Science – IAHS*, Milan, 455-462.

- Rodrigues, M.F.S., Teixeira, J. and Cardoso, J.C. (2011), "Buildings envelope anomalies: A visual survey methodology", *Construction and Building Materials*, 25, 5, 2741-2750
- Roulet, C.-A., Flourentzou, F., Labben, H.H., Santamouris, M., Koronaki, I., Dascalaki, E. and Richalet, V. (2002), "ORME: A multicriteria rating methodology for buildings", *Building and Environment*, 37, 6, 579-586.
- Salim, N.A.A. and Zahari, N.F. (2011), "Developing Integrated Building Indicator System (IBIS) A Method of Formulating the Building Condition Rating", *Procedia Engineering*, 20, 256-261.
- Shohet, I.M. (2003), "Building evaluation methodology for setting maintenance priorities in hospital buildings", *Construction Management and Economics*, 21, 7, 681-692.
- Shohet, I.M. and Lavy, S. (2004), "Development of an integrated healthcare facilities management model", *Facilities*, 22, 5/6, 129-140.
- Uzarski, D.R., Grussing, M.N. and Clayton, J.B. (2007), "Knowledge-based condition survey inspection concepts", *Journal of infrastructure systems*, 13, 1, 72-79.
- Vanier, D.J., Tesfamariam, S., Sadiq, R. and Lounis, Z. (2006), "Decision models to prioritize maintenance and renewal alternatives", in *Joint International Conference on Computing and Decision Making in Civil and Building Engineering*, Montréal, QC, 2594-2603.

5.3

QUESTIONNAIRE DESIGN FOR OBJECTIVE EVALUATION OF PERFORMANCE OF BUILT FACILITIES

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ABSTRACT

Purpose: Develop a questionnaire for evaluation of performance of built facilities using attribute descriptors that can elicit more objective user response during user satisfaction surveys.

Background: Among present methods in vogue to elicit user feedback, questionnaire remains the foremost and most common tool. Questionnaires presently being used to gauge user satisfaction being subjective, feedback obtained do not necessarily reflect actual performance. Hence, there is a requirement of a survey instrument to gauge user satisfaction that truly reflects ground reality. Such survey instrument comprises of questions framed on various attributes of a built facility. These attributes need appropriate description for incorporation in a survey instrument.

Approach: This study is based on a number of case studies in performance evaluation. It identifies a methodology where questionnaire formulation can be made more objective using attribute descriptors that indicate user satisfaction, depending on the purpose of survey and the type of facility. The study involves a pilot survey in a hospital building for validating the questionnaire.

Results: The data obtained in the form of user feedback has been analyzed to validate the survey instrument for its translational validity, construct validity and internal consistency.

Practical implications: This study provides examples in formulation of attribute descriptors and a methodology for questionnaire design. It also brings out necessity of a vernacular questionnaire and trade off between length of questionnaire and objectivity.

Research limitations: The study is based on a few case studies which limit the possibility to generalise and the new methodology for questionnaire design needs further validation.

Originality/value: The study provides a more systematic approach to question formulation during questionnaire design and represents an original contribution to the development of knowledge and methodology in questionnaire design for objective evaluation of performance of built facilities.

Keywords: Facility performance evaluation, User satisfaction, Questionnaire, Attributes, Descriptors, Pilot survey, Validity

1 INTRODUCTION

The primary purpose of buildings is to meet the needs/expectations of users/occupants in providing with conducive, safe, comfortable, healthy and secured indoor environment to carry out different kinds of activities ranging from work, study, leisure and family life to social interactions. (Eziyi Offia Ibem et. al., 2013) Buildings are constructed and managed based on standards and specifications established by governments, professionals and experts who are supposed to have adequate knowledge of users' needs and expectations. (Meir et.al, 2009) But these standards and specifications do not conform to the changing needs and expectations of users. (Kian et. al., 2001) Building performance can be enhanced by regular performance evaluation, exploring and understanding users' needs, expectations and aspirations. (Kim et. al., 2005, Nawawi and Khalil, 2008) Put succinctly, building performance evaluation primarily seeks to improve the quality of design, construction and management of buildings and by extension, promotes sustainable built environment. (Eziyi Offia Ibem et. al., 2013) It also helps in understanding how occupants feel about their buildings, and thus provides basic information on users' needs, preferences and satisfaction. (Vischer, 2008) User feedback is obtained through questionnaire and its content depends on the purpose for which the surveys are carried out. Purposes may be issues pertaining to technical, functional, financial, environmental, societal aspects etc. And the satisfaction level can be measured through metrics/indicators called attributes. In order to obtain right feedback, structuring of questionnaire becomes vital. Such survey instrument comprises of questions framed on various attributes of a built facility. The purpose of survey dictates the nature of questions and the attributes that indicate these purposes and can be categorized into different groups. These attributes need appropriate description for incorporation in a survey instrument. This study is aimed at developing a survey instrument using appropriate descriptors for chosen attributes that indicate building performance from user point of view. The study also involves a pilot survey in one of the buildings of a hospital for checking the validity of such a survey instrument, developed for objective evaluation of performance of built facilities.

2 OBJECTIVE AND METHODOLOGY

2.1 Objective

The aim of this study is addressing an issue in questionnaire design, towards improving the objectivity in user response obtained through questionnaires. The focus area of this study is to develop a questionnaire based on attribute descriptors to elicit user objective user feedback in performance evaluation of built facilities.

2.2 Methodology

In order to achieve the above objective, the under mentioned methodology was formulated:

- Literature survey to understand theoretical issues related to the objective
- Present methods of question formulation
- Identification of attributes that indicate user satisfaction in building performance

- Illustration of sample descriptions for two attributes based on theoretical content
- Item generation for the questionnaire based on the sample descriptors
- Design of a questionnaire based on the attribute descriptors
- Pilot survey for validation of the questionnaire

3 STATE OF THE ART

3.1 User satisfaction

With the paradigm shift of focus of the industry from output based to outcome based facility performance evaluation, user satisfaction is considered as one of the best means to evaluate outcome of any built facility. There are different approaches to gauge user satisfaction depending on the facility being assessed. User satisfaction is a measure of difference between the actual and expected performance of the facility in meeting the needs and expectations from users' point of view. (Eziyi Offia Ibem et al, 2013). In order to assess user satisfaction, the primary requirement is to exactly identify the attributes that a user looks for in any built facility. These attributes shall vary depending upon the type of facility like buildings, roads etc. In case of buildings, the indicators can cover the technical, functional and behavioural aspects of the buildings. (O'Sullivan et al., 2004, Khair et al., 2012) User satisfaction also depends on the characteristics of users like their social, economic and educational background, personal likes and dislikes etc. A wide range of tools and approaches have been developed in the recent years for building performance evaluation of office, residential, commercial buildings. (O'Sullivan et al., 2004, Kim et al., 2005, Khair et al., 2012) In case of buildings, the occupants/residents build expectations on performance in terms of benefits it will provide and the needs it should meet. The building may be perceived by the same people differently at different times or differently by different people at the same time. Also, the expectations vary among different individuals, groups and communities. (Kim et al., 2005) Literature review points out that even though expectations of users and the community with respect to buildings are diverse, the same can be measured in terms of indicators or attributes. (Kian et al., 2001, Meir et al., 2009)

3.2 QUESTIONNAIRE AS A SURVEY INSTRUMENT

3.2.1 Questionnaire

Questionnaire is a well-established tool for acquiring information on participants' social characteristics, standards of behaviour or attitudes and their beliefs and reasons for action with respect to topic under investigation. (DK Bird, 2009) Questionnaire is a measuring device used to query a population/sample in order to obtain information for analysis. (PMT, Fairfax County, 2007) Questionnaires enable collection of information in a standardized manner which, when gathered from a representative sample of a defined population allows the inference to a wider population. (Janice Rattray and Martyn C Jones, 2005) Cognitive research into survey methodology starts from the premise that responding to survey questions involves many, frequently iterative, steps of complex information processing. The process begins with comprehension of the question and proceeds to the retrieval of relevant information. (Petra Lietz, 2009)

3.2.2 *Stages in formulation of questionnaire*

Formulation of any questionnaire undergoes the following stages.

(a) Content of the questionnaire – When developing a questionnaire, items or questions are generated that require the respondent to respond to a series of questions or statements. Participant responses are then converted into numerical form and statistically analyzed. Hence, the content in the questionnaire must be reliably operationalize the key concepts detailed within specific research questions and must, in turn be relevant and acceptable to the target group. (Janice Rattray and Martyn C Jones, 2005)

(b) Range of scale – There are range of scales and response styles that may be used in developing a questionnaire. These produce different types of data levels and this will influence the analysis options. Hence, it is important to be clear on the range of scale and the style of response that need to be adopted in formulating the survey instrument. Though many types of frequency scales like Thurstone scales, Guttman scale, Rasch scale are available, likert scale is the most widely used frequency scale. Likert scale use fixed choice response formats and are generally used to measure attitudes and opinions. Likert type scale assumes that the intensity of experience is linear i.e. on a continuum from strongly agree to strongly disagree and also assumes that the attitudes can be measured. Generally, a likert scale of 5 is adopted for measuring satisfaction levels of participants. (Janice Rattray and Martyn C Jones, 2005)

(c) Item generation, wording and order – Generation of items during questionnaire development requires considerable pilot work to refine the wording and content. Items need to be generated from a number of sources including consultation with industry experts, proposed respondents and also extensive literature review. This stage is a very important stage as the type of question, language used and the order of items may all bias response. Consideration should be given to the order in which items are presented e.g. it is best to avoid controversial or emotive items at the beginning of a questionnaire. In order to keep the participant engaged, data like demographic details can be presented at the end of the questionnaire. Certain types of questions should be avoided e.g. those that lead or include double negatives or double barreled questions. A mixture of both positively and negatively worded items may minimize the danger of acquiescent response bias i.e. the tendency of the respondent to agree with a statement or respond in a same way to questions. In certain cases, open ended questions may interest the respondents. But it may be difficult to interpret, quantify and analyze the input from such open ended questions. (Janice Rattray and Martyn C Jones, 2005)

(d) Validation – In the process of developing a questionnaire, it is very important to conduct a pilot survey to validate the survey instrument. (Janice Rattray and Martyn C Jones, 2005) Validation of a questionnaire involves the following three stages. (Nasrin Parsian and Trisha Dunning, 2009)

- (i) Translational validity – through content validity and face validity
- (ii) Construct validity – through principal component analysis of variables
- (iii) Reliability – through internal consistency and test-retest

3.2 Present trends in question formulation

3.2.1 *Example 1*

Eziyi Offia Ibem et al., (2013) have carried out measurement of performance of public housing based on user satisfaction. Review of their questionnaire indicates that the design of ques-

tions might not elicit the exact response from the users that the researchers were looking for. The questions were designed based on the attributes. The manner in which the questions were framed, the participant may not truly perceive what the researcher might be meaning about the attribute, leaving it to the imagination of the participant to respond. Ultimately, the response of the user may be subjective or arbitrary. One of the sample questions is depicted in Figure 1.

Figure 1: A sample of the format used by Eziyi Offia Ibem et al (2013)

How satisfied or dissatisfied are you with the house where you live in terms of the following? Please tick (✓)					
Building attributes	Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied
Building type					
Quality of natural light					
Quality of artificial light					

3.2.2 Example 2

Two sample questions of a questionnaire used by the Energy Systems Research Unit, University of Strathclyde, UK in a questionnaire for post occupancy evaluation is depicted in Figure 2 and Figure 3 below.

Figure 2: A sample question for occupant of a dwelling unit used by ESRU, UK (2010)

4. How safe do you feel in the building ? (with 1 being very unsafe to 5 being very safe):					
<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5	
additional comment					
<div></div>					

Figure 3: A sample question for occupant of a dwelling unit used by ESRU, UK (2010)

5. How would you describe the amount of natural daylight overall in the building ? (with 1 being very unsatisfactory to 5 being very satisfactory):					
<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5	
additional comment					
<div></div>					

(a) In the sample question depicted in fig 2, safety can be interpreted by respondents in the form of physical safety, fire safety, safety against calamities, safety against theft and burglary, and so on. This interpretation will depend on factors like social, economic, educational and financial background of the respondent. The researcher might not exactly be conveying the information that he requires from the respondent, which may lead to arbitrary response.

(b) Similarly, in the sample question depicted in fig 3, 'amount of natural light' leading to satisfaction will again vary depending on the tasks being performed, characteristics, personal likes and dislikes of the respondent etc. Also, by providing space for additional comments in every question may result in the respondent recording contradictory information with respect to the rating and the description on additional comments. This may render the response inconsistent.

3.3 Attributes

3.3.1 Attributes are functions/metrics/indicators through which performance of a facility can be measured. These attributes vary depending on the type of facility and the purpose of performance evaluation. The selection of attributes also depends on the type of users like occupants, managers, supervisors etc. The choice of attributes should be made in such a manner that they are useful in holistic as well as assessment of any specific aspect of a facility. (Sarel Lavy et. al., 2011) In case of performance evaluation of buildings also, the selection of attributes is governed by the purpose of the evaluation. Literature survey on building performance evaluation indicates that a no of researchers have grouped various attributes together depending on the purpose of evaluation of the building. Many of the attributes have been clubbed as under in different groups by the various researchers. However, choice of attributes is generally governed by the intended purpose of the evaluation.

3.3.2 While measuring residential satisfaction in a housing colony, Mohammad Abdul Mohit and Mohammad Azim, (2011) grouped 46 attributes in four components namely under housing and physical features, services provided within housing area, public facilities provided and social environment within housing area. While assessing maintenance aspects of a high rise office building complex, N.E.M Nik-Mat et. al., (2011) grouped 16 attributes in three different heads namely functional, technical and image characteristics. Eziyi Offia Ibem et. al., (2013) listed 27 attributes under five factors while carrying out performance evaluation of residential buildings. Natasha Khalil et. al, (2009) identified 19 attributes for building performance while carrying out post occupancy evaluation of public buildings. Xianhai Meng and Michael Minouge, (2011) had used 11 indicators while measuring maintenance performance of buildings. Ahmed E Hashim et. al., (2012) used 10 attributes under four heads namely space, comfort, serviceability and safety.

3.3.3 There are other case studies (Abdul Lateef et al, 2011, Igal M Shohet et. al., 2003) available too, wherein the performance of a built facility is assessed based on a number of factors. The modus operandi for all such assessments has been to obtain feedback from various agencies including occupants/users through questionnaire. In all these methods, there is a scope of bringing more objectivity in response of the users by improving the manner in which the questions are put across to the participants in the user satisfaction surveys.

3.4 Attributes for building performance evaluation

3.4.1 In order to assess building performance, literature survey was carried out identify the attributes that indicate user satisfaction on building performance. Initially 56 attributes were

identified which was reduced to 29 after closely scrutinizing these attributes with respect to the purpose of evaluation. A list of these attributes was circulated amongst construction industry experts including architects, engineers, consultants and academicians. Interaction was carried out through email and personal interviews to draw their opinion on adequacy and appropriateness of the attributes for building performance evaluation. 19 responses were received that lead to the choice of attributes listed in Table 1 as adequate to obtain user satisfaction level while evaluating performance of a built facility. A cryptic mention of aspects covered by each attribute is also made against each.

Table 1: Attributes for building performance evaluation

S No	Attributes	
1	Physical condition	Building integrity like cracks, leakage, seepage, dampness etc
2	Space	Size/grouping of rooms, common areas, open spaces etc
3	Indoor air	Ventilation and air conditioning for thermal comfort
4	Illumination	For adequacy and visual comfort
5	Safety and security	Against fire, lightning, accidents, infections, insects and crime level
6	Accessibility	Connectivity, internal roads, staircases, lifts, escalators
7	Air, Noise and water	Environmental aspects of quality of air, water and noise
8	Waste disposal	Including garbage collection and disposal
9	Drainage	Rain water, sewage and sullage
10	Finishes	Internal and external finishes
11	Amenities	Drinking water, washrooms, water and electricity supply etc
12	Aesthetics	Including landscaping, visual comfort, psychological comfort etc
13	Parking	Its location and adequacy

3.4.2 There is a requirement to put across the above questions in a manner that a participant in the survey, irrespective of his background, perceives the requirement of the researcher and offer an objective feedback. Though the rating of users may vary depending on their social, economic, educational, financial background etc, the researcher can ensure to convey what he exactly looks for in their reply, through adequate description of each attribute. This description facilitates forming of each item as a question under each attribute. National Building Code 2005 (India) which is followed across the country as baseline for construction projects in India has been referred to formulate characteristics of each attribute. Descriptors for two attributes ‘Safety and security’ and ‘Illumination’ are enumerated in the following paragraphs.

(a) Description of safety and security – In order to formulate questions on safety and security, the attribute ‘safety and security’ is described in Table 2 below.

Table 2: Description of safety and security

S No	Characteristic	Description
1	Physical safety	Provides safety against accidents due to falling, tripping etc
2	Safety against insects	Protects from insects in the form of mosquito proofing, Fumigation etc
2	Fire safety	With adequate fire extinguishers, water sprinklers, fire alarms etc
		Placed at prominently visible places for access
		Has signboards indicating location of equipment, fire exits
		With passages and fire exits free of obstructions
		Sufficient ventilation to avoid choking due to smoke during fire
		With adequate water supply dedicated for fire fighting
4	Electric safety	Against electrical accidents due to loose fittings, wires etc
5	Security	Against theft, burglary, crime rate in the area etc

(b) Description for illumination – As lighting comprises of both natural and artificial lighting, in order to obtain the satisfaction level of the users on lighting, the attribute has been named more appropriately as ‘Illumination’ description of which is described in Table 3 below.

Table 3: Description of illumination

Characteristic	Description
Uniformity	Uniformly lit to perform the tasks and improve performance
Glare	Has proper shading devices to avoid glare
Visual comfort	Does not cause any visual discomfort like flickering, over lighting
Safety	Promotes safety of occupants during movement
Control	Has easily accessible control to both natural and artificial lighting
Lighting type	Also provides for natural lighting
Appearance	Improves the appearance of the area
View	Has a choice for view to outside
Psychological effect	Has positive psychological impact on the occupant
Maintenance	Facilitates easy access and handling for maintenance
Energy savings	Facilitates energy savings

3.4.3 Only two examples of descriptors for safety and security and illumination have been included in this paper to illustrate the formulation. Similarly, characteristics and descriptions for each attribute identified as relevant to the type of evaluation can be framed and incorporated in the survey instrument so that the ultimate goal of obtaining objective feedback from the users/occupants is achieved. The descriptions for each attributes are drawn bases on the theoretical content that characterizes the attributes. Relevant literature needs to be referred to, in order to describe the attributes. In the Indian context, the descriptions of attributes were formulated predominantly referring to the national building code, 2005.

3.4.4 Once the descriptors for an attribute are formulated, they need to be transformed in the form of questions. Basic rules of question formulation like avoiding double barreled questions, negative terminology and simple language should be followed while generating the questions. Threatening questions, ambiguous questions, danger words, questions leading to bias and generic questions also should be avoided in the process.

3.5 Questionnaire for building performance evaluation

3.5.1 A questionnaire was designed for building performance evaluation based on descriptors of attributes mentioned in table 1. The following points were kept in mind while formulating the questions.

- (a) Likert scale of 5 has been uniformly adopted for all questions.
- (b) The questions are all predominantly 'How' with an aim to obtain the opinion of respondents with respect to what they feel about each and every item related to the variable.
- (c) All the questions are framed positively starting with 'Highly positive opinion' rated 1 and 'Highly negative opinion' rated 5.
- (d) The ratings are labeled specific to the nature of opinion likely to be endorsed by the respondent rather than keeping it common to all the questions like 'Highly satisfied' to 'Highly dissatisfied'
- (e) The questionnaire has been divided into four sections. Section I comprises of demographic details of the respondents that will enable confirm the sampling population. Section II comprises of the technical content wherein all the questions are grouped under each attribute. Section III is a section dedicated to additional comments, wherein the respondent can record his/her additional comments and opinions on building performance. Section IV lists down all the attributes and asks the respondent to rank them in order of importance. This will enable the researcher to understand the weightage the respondent had in his/her mind while rating every item under each attribute.
- (f) The section IV of the questionnaire has been incorporated to give an idea to the researcher on the degree of importance the occupants attach to each attribute from which the researcher can derive the weightage to be allotted to the ratings of these attributes during analysis.

3.6 Pilot survey

A pilot survey was undertaken to check the validity of the questionnaire. One of the buildings of a government hospital in Mumbai was chosen for the study. The user profile of the building was studied and the sampling was carried out as per stratified random sampling technique. The questionnaire was administered to a sample size of 100 (n) among doctors, nursing staff, patients, administrative staff, lab technicians and maintenance staff. The survey was conducted through distribution of questionnaire to all participants other than patients. The feedback from the patients was obtained on a vernacular questionnaire (in local language i.e. Marathi, being Mumbai) through personal interaction. The exercise was carried out over a period of 10 days and in total 54 responses were received and used for data analysis.

4 RESULTS

4.1 Translational validity

The content and face validity of the questionnaire was checked by circulating the questionnaire amongst industry experts including architects, engineers, consultants and academicians. Interaction was carried out through email and personal interviews to draw their opinion on adequacy and appropriateness of the attributes for building performance evaluation. 19 responses were received and the questionnaire was fine tuned based on the inputs received, before venturing into the pilot survey

4.2 Construct validity

Since the questions were framed based on attribute descriptors, they were grouped under relevant attributes. It was felt that exploratory factor analysis was not required in this case. A confirmatory factor analysis was carried out to check the construct validity of the instrument. Adequacy of sample size to carry out factor analysis was also checked.

4.3 Reliability

The reliability of the questionnaire was checked through internal consistency reliability. The cronbach item inter relation coefficient for the attributes varied from 0.7 to 0.9, which indicates a good correlation between the items and the questionnaire is consistently reliable.

5 PRACTICAL IMPLICATIONS

5.1 Implications of the descriptors

As brought out in sections 3 and 4 above, describing the attributes clearly will enable formulation of question items properly which will in turn enable the respondent to comprehend the attribute holistically. Through this description, the researcher also can be assured of conveying what exactly the researcher looks for in a particular attribute. This process will improve the quality of user feedback and reduce the subjectivity in their responses. The attributes may vary depending on the type of the built facility whereas the similar process of descriptors before formulation of questions can be followed for objective evaluation.

5.2 Vernacular questionnaire

During the conduct of the pilot survey, it was found that use of vernacular questionnaire will enable instant rapport and better communication with the participants. Hence the questionnaire was translated into Marathi and administered to the participants who preferred the vernacular questionnaire.

5.3 Length of the questionnaire

Though the process of generation questions based on descriptors entailed more number of questions, the participants were enthusiastic in their response to the questionnaire. Hence it was felt that the objectivity likely to be obtained through this questionnaire is a good trade off for the questionnaire length. It took approximately 25 to 35 minutes for the participants to complete the questionnaire.

6 CONCLUSIONS

A near correct picture of actual performance of the built facility from the user point of view will enable facility managers to address pertinent issues. Objectivity can be brought into the questionnaire by carefully describing the attributes and transforming them into sub questions as discussed above. Such type of questionnaire is likely to elicit more objective response from the users which will be a near correct reflection of ground reality. Effectiveness of the questionnaire and utility of data obtained depends on the choice of correct attributes, appropriate identification and description of their characteristics and converting them into easily understandable questions. The questionnaire designed for building performance evaluation has been validated and found consistent for subsequent application in user satisfaction surveys.

REFERENCES

- [1] Ahmad E Hashim, Hasnizan Aksah and Sharul Yani Said, (2012), “*Functional assessment through post occupancy review on refurbished historical public buildings in Kuala Lumpur*”, Journal of social and behavioural sciences, Elsevier Procedia, Vol 68, pp 330-340
- [2] DK Bird, (2009), “*The use of questionnaires for acquiring information on public perception of natural hazards and risk mitigation –a review of current knowledge and practice*” Journal of Natural Hazards and Earth System Sciences, Copernicus Publications, Vol 9, pp1307-1325
- [3] Energy System Research Unit, (2010), “*Post occupancy evaluation questionnaire*”, University of Strathclyde, UK
- [4] Eziyi Offia Ibem, Akunnaya P. Opoko, Albert B. Adeboye and Dolapo Amole, (2013), “*Performance evaluation of residential buildings in public housing estates in Ogun State, Nigeria: Users’ satisfaction perspective*”, Elsevier Science direct, Frontiers of Architectural research, Vol 2, pp 178-190
- [5] Igal M Shohet, Sarel Lavy-Leibovich and Dany Bar-On, (2003), “*Integrated Maintenance Management of Hospital Buildings in Israel*”, Journal of Construction Management and Economics, Vol 21, pp 197-208
- [6] Janice Rattray, Martyn C Jones, (2007), “*Essential elements of questionnaire design and development*”, Journal of Clinical Nursing, Vol 16, pp 234-243
- [7] Khalil N, Nawawi AH (2008), “*Performance assessment of government and public buildings via post occupancy evaluation*”, Asian School of Science, Vol 4(9), pp 103-112
- [8] Kian PS, Feriadi H, Sulistio W, Seng KC (2001), “*A case study on total building performance evaluation an intelligent office building in Singapore*”, Dimensi Teknik Sipil, Vol 3(1), pp 9-15
- [9] Kim S, Yang I, Yeo M and Kim K, (2005), “*Development of a housing performance evaluation model for multifamily residential building in Korea*”, Journal of Building and Environment, Vol 40, pp 1103-1116
- [10] Meir IA, Garb Y, Jiao D, Cicelsky A, (2009), “*Post Occupancy Evaluation: An inevitable step towards sustainability*”, Advances in Building energy and research, Vol 3, pp 189-220
- [11] Mohammad Abdul Mohit and Mohammad Azim, (2012), “*Assessment of residential satisfaction with public housing in Hulhumale’, Maldives*” Journal of social and behavioral sciences, Elsevier Procedia, Vol 50, pp 756-770
- [12] Nasrin Parsian, Trisha Dunning AM, (2009), “*Developing and validating a questionnaire-A psychometric process*”, Global Journal of Health Science, Vol 1, No 1, pp 2-10

- [13] Natasha Khalil, Husrul Nizam Husin, Hamimah Adnan and Abdul Hadi Nawawi, (2010), “*Correlation analysis of building performance and occupants’ satisfaction via post occupancy evaluation for Malaysia’s public buildings*”, Munich Personal RePEc Archives, paper No 19634
- [14] The National Building Code, 2005, Government of India Publications
- [15] Petra Lietz, (2009), “*Research into questionnaire design-A summary of the literature*”, International Journal of Market Research, Vol 52, Issue 2, pp 249-272
- [16] PMT Fairfax County, (2007), “Manual for surveying for customer satisfaction”, Department of Management and Budget, United Kingdom, pp 1-17
- [17] Sarel Lavy, John A. Garcia and Manish K Dixit, (2011), “*Establishment of KPIs for facility performance measurement: Review of Literature*”, Journal of facilities, Emerald Group Publishing, pp 445-464
- [18] Vischer JC, (2008), “*Towards a user centred theory of built environment*”, Journal of building research and information, Vol 36(3), pp 231-240
- [19] Xianhai Meng and Michael Minouge, (2011), “*Performance Measurement Models in Facilities Management*”, Journal of Facilities, Emerald Group Publishing, Vol 29, pp 472-484

CHAPTER 6

ENERGY MANAGEMENT

6.1

Investigating the Energy Performance and Maintenance Resources of Quality Hotels in Hong Kong

Joseph H.K. Lai

6.2

A Facility Management Approach to Reducing Energy and Carbon Footprint of Built Facilities

M.K. Dixit, C.H. Culp, J.L. Fernandez-Solis and S. Lavy

6.3

Assessing the Energy Efficiencies of Individual Departments within Universities with the ‘DEA Energy Management System’: An Empirical Study

Kung-Jen Tu

6.1

INVESTIGATING THE ENERGY PERFORMANCE AND MAINTENANCE RESOURCES OF QUALITY HOTELS IN HONG KONG

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ABSTRACT

Purpose: The study reported in this article aimed to identify the relations between the resources used for maintaining hotels and their energy uses.

Background: Past studies have researched into either the energy side or the maintenance aspect of some existing hotels. Analyses focussing on the empirical relation between maintenance resources and energy performance of hotels remain unavailable.

Approach: Detailed and reliable data were obtained through face-to-face interviews with the senior maintenance staff of 20 quality hotels in Hong Kong. Descriptive statistics and benchmarking curves of the hotels' energy consumptions and maintenance resources were worked out. Correlation analyses were made between the energy consumptions and the maintenance resources.

Results: The energy use of the hotels was dominated by electricity consumption. Generally the cost for implementing capital projects outweighed the cost for hiring maintenance staff or executing repair and maintenance works. Hotels with greater investment in capital projects used less energy, which highlighted the link between energy performance and works done for improving the energy efficiencies of hotel facilities.

Practical Implications: Benchmarks and benchmarking charts were established for use in evaluating energy performance and maintenance effectiveness of hotels.

Research Implications/limitations: Future studies may use a similar methodology to investigate the energy performance and maintenance resources of hotels or other types of buildings elsewhere. The present study findings were based on a sample of 20 hotels. More representative findings would be obtained when more samples are included in the analysis.

Originality/value: An original and useful finding was the existence of connection between energy performance of hotels and resources used for carrying out capital projects to improve the condition of their facilities.

Keywords: Benchmark, Energy use, Hong Kong, Hotel, Maintenance

1 INTRODUCTION

The global energy consumption has continued to rise. The use of energy in urban areas, especially those developed with a high density of commercial buildings, has become progressively intensive. This has led to various environmental issues, particularly the growth of greenhouse gas emission, which is central to the global warming problem.

Hong Kong, a developed city in Asia, is famous for its overcrowded high-rise buildings. Being a popular tourist destination, it received over 48.6 million visitors in 2012, among them over 23.7 million were overnight visitors and their average length of stay was 3.5 nights (Tourism Commission, 2013). Accommodating these visitors were many sizable hotels built with quality facilities; they include not only engineering installations such as chiller, boiler, lift, and lighting but also leisure facilities like swimming pool, sauna, gym equipment, and so on.

According to the government's statistics (Electrical and Mechanical Services Department, 2012), the biggest share (42%) of the total energy use of Hong Kong was due to the commercial sector. Hotels belong to the commercial segments that used 63,962 TJ (Terajoule; 1 TJ = 10^{12} J) in 2010, a substantial increase from 40,255 TJ in 2000. Therefore it is necessary to optimize or minimize the energy use of the hotels in order to help reduce the growth of energy consumption of Hong Kong.

The energy use of hotels is dependent on a multitude of factors over their building life cycle, including designed efficiency of their facilities; installation workmanship and hence constructed quality of the facilities; whether the facilities have been properly tested and commissioned before use; and how well the facilities are operated and maintained. It is well-recognized that the energy use as well as occupancy cost during the operation and maintenance stage of a building life cycle prevail over the costs of the other stages (Evans et al., 1998). Yet little has been done to research into the relation between energy performance and maintenance effectiveness of hotels. Aimed at contributing knowledge to this area, a study was carried out, as reported in this article.

In the next section, a review of the past research works that are relevant to the present study is presented. Section 3 describes the theory based on which the objective of the study was formulated and the methodology used for data collection and analysis of the data collected. The analysed findings are reported in section 4, which include benchmarks of the energy consumptions and maintenance resources of the hotels studied, and correlations between various parameters of the consumptions and resources. Lastly, section 5 summarises the conclusions drawn from the study results and the future works needed.

2 PAST RELEVANT STUDIES

Over the years, numerous research studies have been carried out to study the energy use of buildings, including many that were focused on hotel buildings. In studying the efficiency of hotels, some research works (e.g. Barros, 2005; Neves and Lourenco, 2008) investigated parameters such as business performance (e.g. revenue, return on investment), management or administrative expenses (e.g. labour cost, front-of-the-house hours). In view of the limited findings about operation and maintenance (O&M) costs of hotels, Lai and Yik (2008) carried out a benchmarking study based on 10 luxury hotels in Hong Kong, which unveiled that large

amounts of resources were used for maintenance and that energy cost was the greatest O&M expenditure of the hotels.

Among the major costs-in-use of buildings, energy consumption has attracted the most attention. In Hong Kong, Deng and Burnett (2002) investigated the energy use of 16 quality hotels, which was found to be dominated by electricity consumption. The study of Bohdanowicz and Martinac (2007), which covered a sample of 184 Hilton International and Scandic hotels in Europe, investigated the utilizations of energy and water in the hotels. Based on a survey of 29 quality hotels in Singapore, Rajagopalan et al. (2009) found that the average total energy use intensity of the hotels was 427 kWh/m². In Taiwan, the study of Wang (2012) collected the data of 200 hotels and revealed that on average electricity consumption accounted for 84% of their total energy use.

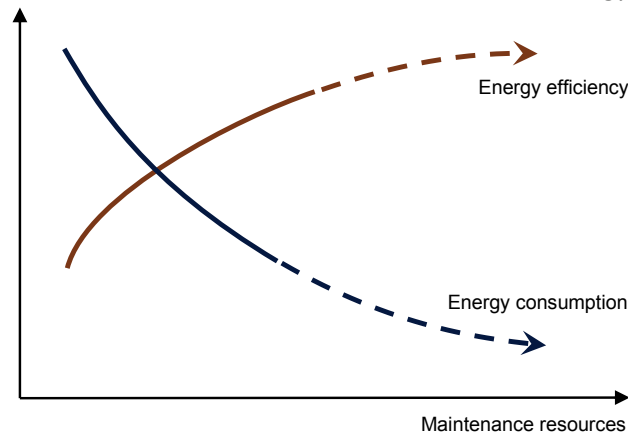
In recent years, studies that probed into the maintenance performance of hotels have emerged. Particularly, the study of Lai and Yik (2012a), conducted based on the computerized maintenance management data of a 618-room hotel, identified the existence of a significant correlation between equipment downtime and amount of maintenance work orders, and developed a range of performance curves for assessing maintenance performance of hotel engineering facilities. Meanwhile, it was found that the work efficiency of the hotel's maintenance workforce declined with increasing utilization levels of the workers (Lai and Yik, 2012b). Furthermore, Lai (2013) introduced a model that enabled analysing maintenance data according to the period, place, and physical installation ("3P") of the maintenance works. The analyses carried out in that study showed that the maintenance works for the hotel were highly correlated with their demands but had little correlations with the input manpower.

The above studies had delved into either the energy side or the maintenance aspect of some existing hotels. The work of Chan et al. (2003) was among the limited studies that attempted to explore both the maintenance practices and energy performance of hotels. Performance-based models that can link built asset maintenance with the strategic performance of buildings, however, have yet to be developed (Jones and Sharp, 2007). Not long ago, three case studies – a college district, a laboratory building, and a medical center were carried out in the North America (Lewis et al., 2011), which showed the existence of an interdependent link between energy use and maintenance management of the buildings. To date, analyses focusing on the empirical relation between energy performance and input maintenance resources of quality hotels remain unavailable. In order to help in bridging this knowledge gap, a study was initiated.

3 APPROACH

The premise based on which the study was formulated is that the energy performance of hotel buildings is linked with the level of maintenance of the buildings. Theoretically, a higher level of maintenance resources input for a building would allow more and better maintenance work to be carried out, thus enabling the energy-consuming facilities of the building to perform more efficiently, using less energy. Figure 1 conceptualises this idea.

Figure 1: Conceptual relations between maintenance resources and energy consumption/efficiency



Identification of the energy performance of a building can be made by referring to the amounts of utilities the building consumed. Resources used for maintaining a building include those needed to hire maintenance staff, execute routine repair and maintenance work, and implement some capital projects to improve the conditions of the existing facilities. Such utilities and costs data are sensitive and, as experienced before, they were difficult to obtain (Lai et al., 2008). Therefore, individual face-to-face interviews, which assure the confidentiality of the identities of the hotels and the interviewees, were adopted to collect the data needed. In order to identify the utilities consumptions of the hotels and their maintenance resources, a data template was designed. The types of data collected covered: star rating; building age; gross floor area; number of guestrooms; occupancy rate; annual costs of maintenance staff, repair and maintenance work, and capital project; and annual consumptions of utilities including electricity, diesel oil, town gas, and water. The maintenance costs include all those required for the builder's works (e.g. façade, roof, ground) and building services installations (e.g. electrical, air-conditioning, fire, piped services) in the hotels.

The template was provided to the interviewees in advance so as to allow them sufficient time to gather the necessary data. During the interviews, the interviewer explained the coverage of the various categories of data requested. In cases where such coverage was found to be different from that of the data the interviewees provided, minor revisions were made at the time of the interviews. For revisions that were too substantial to be made within the limited interview periods and for data that could not be made available during the interviews, follow-up contacts were made with the interviewees to supplement the outstanding data. Afterwards, the data collected were organized and checked for completeness and any abnormality. For incomplete data and those detected as unreasonable, clarifications were sought from the respective interviewees, before the data were consolidated for analysis.

The analysis was started with figuring out the descriptive statistics of the data, including those about the characteristics of the hotels, and their utilities consumptions and amounts of maintenance resources input. Then, the data were processed to generate benchmarking curves for the various kinds of utilities consumptions and maintenance resources. Finally, the correlations between different parameters of energy consumption and maintenance cost were tested in an attempt to identify the relation between the energy performance of the hotels and their maintenance resources.

4 RESULTS

4.1 Characteristics of the hotels

20 interviewees who were senior engineering staff (e.g. Director of Engineering, Chief Engineer) of the hotels provided useful data for the study. All the hotels were of high quality: 11 were 5-star hotels and 9 were rated as 4-star. There was no new hotel in the sample; the hotel buildings were on average close to 17 years old (standard deviation: S.D. = 9.3), with their mean gross floor area exceeding 41,000m² (Table 1). Collectively there were 10,529 guestrooms in the hotels and the maximum occupancy rate among them was as high as 94%.

Table 1: Characteristics of the hotels

	Mean	Min.	Max.	S.D.
Star rating	-	4	5	-
Building age (year)	16.9	2	34	9.3
Floor area (m ²)	41,401	14,975	65,024	14,359
Guestroom (nos.)	526	113	884	174
Occupancy rate (%)	84.8	65.0	94.0	7.3

The energy use of the hotels was enormous, amounting to a yearly total of over 1,419 TJ. The annual maximum electricity consumption among the samples was up to 109,101 GJ (Giga-joule; 1 GJ = 10⁹ J), which was more than double of the mean consumption level (Table 2). The consumptions of town gas spread over a wide range, from 500 GJ to 55,317 GJ. Diesel oil was not used in all but nine of the hotels; the largest annual consumption among them was 40,007 GJ. Besides, the annual total amount of water consumed by the hotels was 3,256,867 m³, or 309 m³ per room.

Table 2: Annual utilities consumptions of the hotels

	Mean	Min.	Max.	S.D.
Electricity (GJ)	50,197	15,259	109,101	22,605
Town gas (GJ)	11,908	500	55,317	11,984
Diesel oil (GJ)	8,892	0	40,007	13,586
Water (m ³)	162,843	43,305	297,000	61,334

Given that the hotels were large in scale, and high in quality, considerable amounts of resources were deployed to maintain their operations. The relevant cost data of a sampled hotel and the capital project cost data of four others, which the respective hotel owners were reluctant to disclose, were not made available for analysis. Despite this restraint, statistics of the various kinds of maintenance resources, namely repair and maintenance, capital project, maintenance staff, and their overall total, were figured out. Table 3 shows the calculation results and the numbers of samples (*n*) based on which the results were obtained.

The annual cost for providing repair and maintenance works per hotel, on average, was over HK\$8.2 million. The counterpart for financing capital projects of the hotels, including improvement and refurbishment works, was even larger - exceeding HK\$11.1 million. Whereas the average amount of maintenance staff payroll was much less than those of the preceding two kinds of resources, the minimum level of the payroll was actually the highest among the three categories.

Table 3: Annual maintenance resources of the hotels

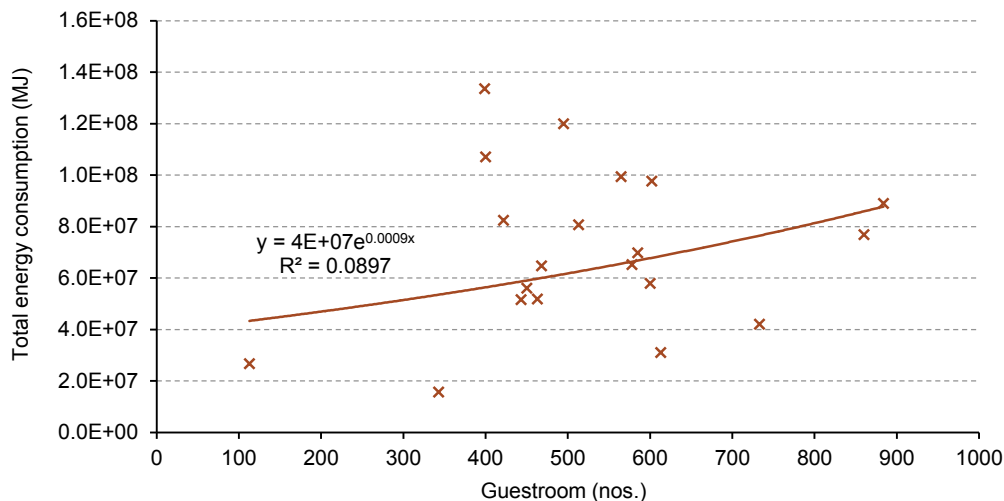
	Mean	Min.	Max.	S.D.
Repair & maintenance (HK\$) [$n = 19$]	8,255,100	1,698,857	18,414,369	4,884,890
Capital project (HK\$) [$n = 15$]	11,126,478	1,191,000	23,000,000	7,502,980
Maintenance staff (HK\$) [$n = 19$]	5,692,214	2,469,018	8,845,669	1,917,371
Total (HK\$) [$n = 15$]	44,117,196	12,253,324	62,898,628	12,745,538

4.2 Normalisation and benchmarking charts

Normally a bigger hotel would be equipped with more facilities and hence require more energy to operate, and vice versa. Since the sizes of the hotels were not identical, it is not meaningful to evaluate their performance by making direct comparisons between their levels of energy consumptions and maintenance resources. In order to enable fair comparisons to be made on the performance parameters, it is necessary to normalise their values with respect to the scale of the hotel buildings.

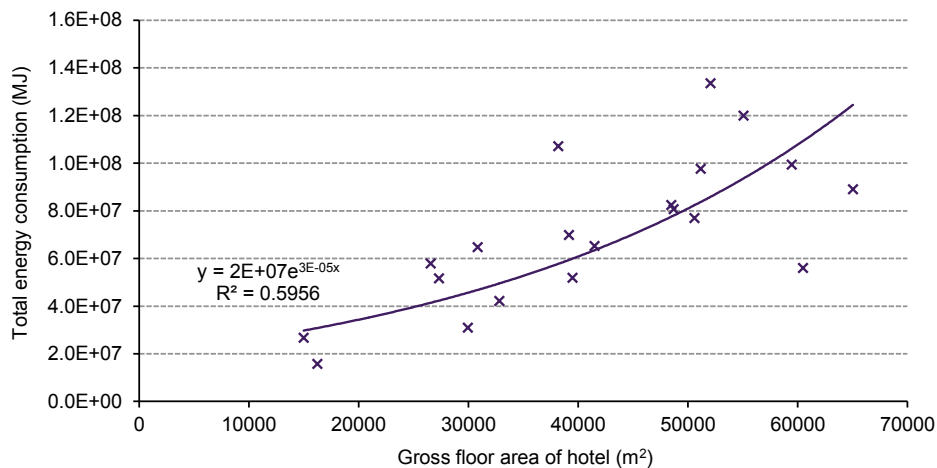
Drawn upon the experience gained from an earlier study (Lai et al., 2008) where some trials were conducted to identify an appropriate normalisation factor for some commercial buildings, an initial attempt was made in the current study to investigate if the levels of energy consumption were dependent on the number of hotel guestrooms. As the scatter plot in Figure 2 shows, the total energy consumptions of the hotels generally increased with the number of their guestrooms. But the former varied widely at the middle range of guestrooms. The R -squared value of the trend line was small, reflecting a low goodness of fit. These observations suggest that number of guestrooms is not good for normalising the total energy consumptions of the hotels.

Figure 2: Relation between total energy consumption and number of guestrooms



A further trial was made by plotting the total energy consumptions against the gross floor areas of the hotels, as shown in Figure 3. It showed that the energy consumptions increased exponentially with the floor areas, and the R -squared value of the trend line was close to 0.6, which was much higher than that of the first trial. Thus, gross floor area can be regarded as a better normalisation factor than number of guestrooms.

Figure 3: Relation between total energy consumption and floor area



In the ensuing analyses, the various kinds of annual energy and water consumptions of the hotels were normalised by their respective gross floor areas. The normalised figures were grouped into bin values and the corresponding cumulative frequencies were plotted to generate some benchmarking charts. Ranging between 811.4 MJ/m² to 2,173.2 MJ/m², the normalised electricity consumptions of the hotels, on average, was 1,223.7 MJ/m² and their cumulative frequencies were as depicted in Figure 4(a). Diesel oil was used in nine of the hotels; its maximum consumption level, at 801.2 MJ/m², was much lower than the counterpart of electricity. While the use of town gas was as common as that of electricity, its consumption levels, with an average value being 311.9 MJ/m², were much lower. Figure 4(d) further shows the cumulative frequency distribution of the normalised water consumptions of the hotels. Unlike the wide-ranging energy consumptions, the variations in the water consumptions were confined to between 2.39 m³/m² and 7.04 m³/m².

Following the way in which the above benchmarking charts were developed, the recourses deployed for maintaining the hotels were normalised by their respective gross floor areas. Such normalised values, including those for repair and maintenance cost, capital project cost, maintenance staff cost, as well as the total maintenance cost, were plotted as shown in Figure 5.

With its minimum value being HK\$66.9/m², the annual amount of repair and maintenance cost reached a maximum value of HK\$908.2/m². The 50th percentile, for instance, was approximately HK\$170/m² (Figure 5(a)). The ranges of the capital project costs and the repair and maintenance costs were of the same order of magnitude, but the 50th percentile of the former costs was much higher, at around HK\$275/m² (Figure 5(b)). Comparatively, the amounts of maintenance staff cost were significantly smaller, ranging between HK\$83.6/m² and HK\$287.2/m² (Figure 5(c)). Overall, the total maintenance cost of more than 80% of the hotels exceeded HK\$1,200/m² (Figure 5(d)).

4.3 Correlation analyses

To test whether the energy use of the hotels was linked with their physical/operational characteristics, a series of correlation analyses, involving the calculation of the Pearson product-moment correlation coefficient (r), was carried out. Table 4 summarised the calculation results as well as the significance values, where n is the number of samples used in the calculation.

Figure 4: Benchmarking charts for utilities consumptions

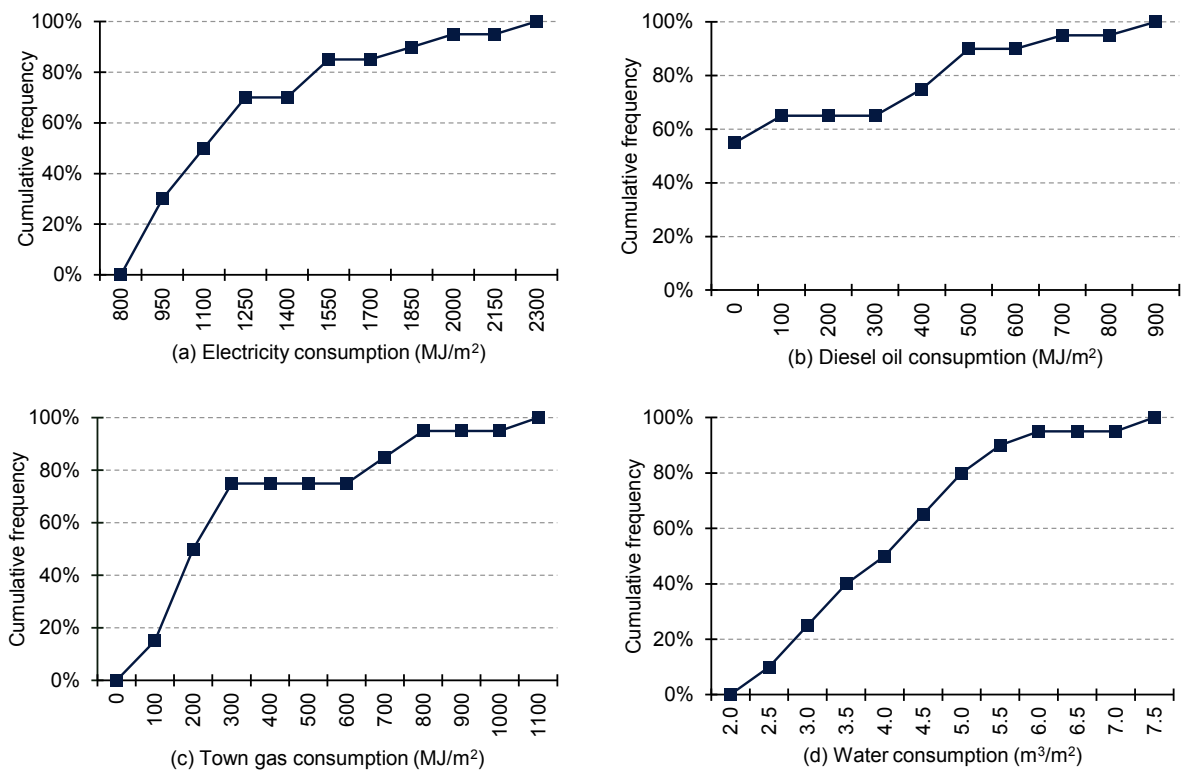


Figure 5: Benchmarking charts for maintenance resources

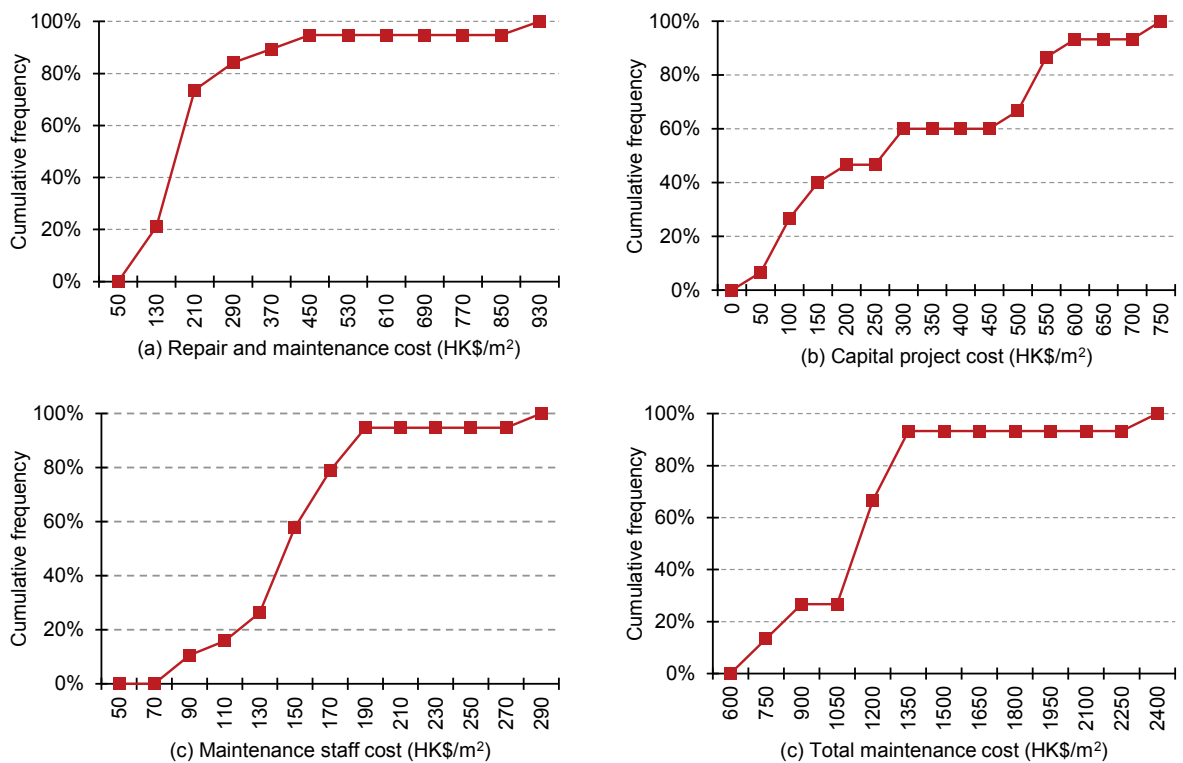


Table 4: Correlations between total energy use and characteristics of the hotels

Parameter	<i>n</i>	Pearson coefficient, <i>r</i>	Sig.
Age (years)	20	0.0574	0.8099
GFA (m ²)	20	0.7280	0.0002**
Guestroom (nos.)	20	0.1759	0.4581
Occupancy (%)	20	-0.3846	0.0940

** correlation is significant at the 0.01 level (2-tailed).

Obviously, gross floor area was found to have a strongly positive correlation with the total energy use of the hotels ($r = 0.7280$; sig. 0.0002), meaning that the bigger the hotel building, the more energy was used. This result is in line with the finding shown in Figure 3. On the other hand, there were no significant correlations between the hotels' total energy use and the remaining parameters. As revealed earlier, number of guestroom was not a good normalisation factor so the absence of significant correlation between this parameter and the total energy use is not unexpected.

As for the age of the buildings, it had no significant correlation with the total energy use. This may be because improvement works for hotels, which cover replacement of energy-inefficient facilities, are typically implemented on a cyclical basis (Lai and Yik, 2012a). Older hotels provided with sufficient improvement works might not be less energy efficient than the newer ones. Whereas it is reasonable to hypothesize that a greater occupancy rate (i.e. higher user density) of the hotels would result in more energy use, the analysis result does not support this hypothesis. Similar to the case of Lai and Yik (2012b), the occupancy rates covered in the analysis, ranging between 65% and 94%, were not wide enough. This is a probable reason for the non-existence of correlation between the total energy use and the occupancy rate.

Further tests were made to investigate if any correlation existed between the total energy use and the maintenance resources used by the hotels. As the results in Table 5 show, there was no significant correlation between the total energy use and the repair and maintenance cost. The same conclusion can be drawn from the findings for the capital project cost and the total maintenance cost. Nevertheless, a moderate, positive correlation was found between the total energy use and the maintenance staff cost ($r = 0.6248$; sig. 0.0042). This implies that more maintenance manpower was required for hotels that consumed more energy.

In order to find out whether a more intensive input of resources for maintaining the facilities would upkeep their energy efficiencies, thereby minimizing their energy uses, it is necessary to investigate the correlations between the total energy use of the hotel buildings and their normalized maintenance resources. To this end, the Pearson's r was computed between the total energy use and each of the maintenance cost categories listed in Table 3. Common to all the categories, they were negatively correlated with the total energy use of the hotels (Table 6). In other words, a lower energy consumption level was associated with a higher intensity of maintenance resources input. Although such correlations for the repair and maintenance cost and the maintenance staff cost were not statistically significant, the correlations for the capital project cost and the total maintenance cost were significant at the 0.05 level.

Table 5: Correlations between total energy use and maintenance resources

Parameter	<i>n</i>	Pearson coefficient, <i>r</i>	Sig.
Repair and maintenance cost (\$)	19	0.3863	0.1023
Capital project cost (\$)	15	-0.3318	0.2269
Maintenance staff cost (\$)	19	0.6248	0.0042**
Total maintenance cost (\$)	15	0.0865	0.7592

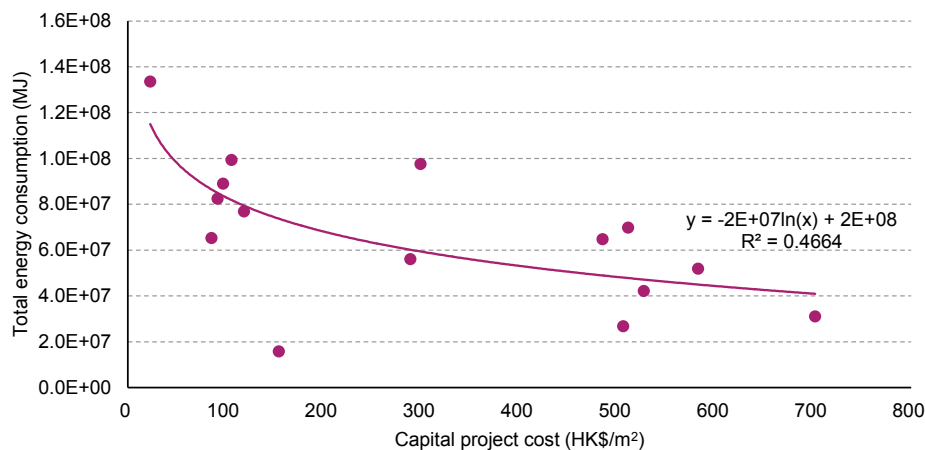
** correlation is significant at the 0.01 level (2-tailed).

Table 6: Correlations between total energy use and normalised maintenance resources

Parameter	<i>n</i>	Pearson coefficient, <i>r</i>	Sig.
Repair and maintenance cost (\$/m ²)	19	-0.1693	0.4884
Capital project cost (\$/m ²)	15	-0.5930	0.0198*
Maintenance staff cost (\$/m ²)	19	-0.3130	0.1920
Total maintenance cost (\$/m ²)	15	-0.5550	0.0317*

* correlation is significant at the 0.05 level (2-tailed).

Figure 6: Relation between total energy use and capital project cost



In light of the comparatively high Pearson's *r* value associated with the capital project cost, a graphical representation of the relation between the total energy consumptions and the capital project costs was prepared, as shown in Figure 6. It is clear that the hotels consumed less total energy with increase in funding for their capital projects, and the decline in energy use followed a logarithmic pattern. This finding suggests that when more intensive investment was made for implementing projects such as replacement of energy-inefficient facilities or improvement of their energy efficiencies, less energy was used by the hotels. Further increase in capital project investment, nonetheless, could only lead to diminishing reduction of energy consumption.

5 CONCLUSION

The study is among the limited research that attempted to investigate the link between energy performance and resources used for maintaining hotel buildings. It showed that among the various energy uses, electricity consumption dominated. The various maintenance resources of the hotels were enormous, with the cost for implementing capital projects being generally more than the cost for hiring maintenance staff or executing repair and maintenance works.

Instead of number of guestrooms, gross floor area was found to be a better parameter for normalising the total energy consumptions of the hotels. Based on the normalised energy and water consumption levels of the hotels, cumulative distribution curves were constructed for benchmarking purposes. Likewise, a set of benchmarking curves was established using the normalised data of the various kinds of maintenance resources. These benchmarking tools can facilitate practitioners to compare and evaluate the energy performance as well as the maintenance effectiveness of similar types of hotels.

Gross floor area, representing the scale of hotels, was the only characteristic parameter exhibiting a strong correlation with the total energy use of the hotels. Generally the larger the hotels, the more resources were needed for hiring maintenance staff. A salient finding from the correlation analyses was that hotels with greater investment in capital projects were less demanding in their total energy use. This highlights the link between energy performance and maintenance works undertaken for improving the condition of hotel facilities.

Further work is needed to examine the effects of factors such as grade, age, and occupancy rate on the maintenance resources as well as energy performance of the hotels. The approach adopted in the study may be taken to investigate the relation between energy performance and maintenance resources of hotels or other types of buildings elsewhere.

ACKNOWLEDGEMENTS

The study reported above was supported by research grant Nos. PL56 & YL82 of The Hong Kong Polytechnic University.

REFERENCES

- Barros, C.P. (2005), "Measuring efficiency in the hotel sector", *Annals of Tourism Research*, Vol. 32, No. 2, pp. 456-477.
- Bohdanowicz, P. and Martinac, I. (2007), "Determinants and benchmarking of resource consumption in hotels – Case study of Hilton International and Scandic in Europe", *Energy and Buildings*, Vol. 39, pp. 82-95.
- Chan, K.T., Lee, R.H.K. and Burnett, J. (2003), "Maintenance Practices and Energy Performance of Hotel Buildings", *Strategic Planning for Energy and the Environment*, Vol. 23, No. 1, pp. 6-28.
- Deng, S. and Burnett, J. (2002), "Energy use and management in hotels in Hong Kong", *International Journal of Hospitality Management*, Vol. 21, pp. 371-380.
- Electrical and Mechanical Services Department (2012), "Hong Kong Energy End-use Data 2012", *The Government of the Hong Kong Special Administrative Region*, HKSAR.

- Evans, R., Haryott, R., Haste, N. and Jones, A. (1998), "The Long Term Costs of Owning and Using Buildings", *Royal Academy of Engineering*, London.
- Jones, K. and Sharp, M. (2007), "A new performance-based process model for built asset maintenance", *Facilities*, Vol. 25, No. 13/14, pp. 525-535.
- Lai, J.H.K. and Yik, F.W.H. (2008), "Benchmarking operation and maintenance costs of luxury hotels", *Journal of Facilities Management*, Vol. 6, No. 4, pp. 279-289.
- Lai, J.H.K., Yik, F.W.H. and Jones, P. (2008), "Expenditure on Operation and Maintenance Service and Rental Income of Commercial Buildings", *Facilities*, Vol. 26, No. 5/6, pp. 242-265.
- Lai, J.H.K. and Yik, F.W.H. (2012a), "Hotel Engineering Facilities: A Case Study of Maintenance Performance", *International Journal of Hospitality Management*, Vol. 31, No. 1, pp. 229-235.
- Lai, J.H.K. and Yik, F.W.H. (2012b), "A Probe into the Facilities Maintenance Data of a Hotel", *Building Services Engineering Research and Technology*, Vol. 33 No. 2, pp. 141-157.
- Lai, J.H.K. (2013), "An analysis of the maintenance demand, manpower and performance of hotel engineering facilities", *Journal of Hospitality & Tourism Research*, Vol. 37, No. 3, pp. 426-444.
- Lewis, A., Elmualim, A. and Riley, D. (2011), "Linking energy and maintenance management for sustainability through three American case studies", *Facilities*, Vol. 29, No. 5/6, pp. 243-254.
- Neves, J.C. and Lourenco, S. (2008), "Performance Evaluation of Worldwide Hotel Industry Hotel Using the Data Envelopment Analysis", Jauhari, V. (Ed.), *Global Cases on Hospitality Industry*, The Haworth Press, New York, pp. 501-522.
- Rajagopalan, P, Wu, X. and Lee, S.E. (2009), "A study on energy performance of hotel buildings in Singapore", *Energy and Buildings*, Vol. 41, pp. 1319-1324.
- Tourism Commission (2013), "Tourism Performance", *The Government of the Hong Kong Special Administrative Region*, HKSAR, available at: http://www.tourism.gov.hk/english/statistics/statistics_perform.html (accessed 12 September 2013)
- Wang, J.C. (2012), "A study on the energy performance of hotel buildings in Taiwan", *Energy and Buildings*, Vol. 49, pp. 268-275.

6.2

A FACILITY MANAGEMENT APPROACH TO REDUCING ENERGY AND CARBON FOOTPRINT OF BUILT FACILITIES

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ABSTRACT

Purpose: The main purpose of this paper is to emphasize the importance of a life cycle approach and the role of facilities management practices in reducing the environmental footprint of built facilities. An approach to holistic life cycle energy and carbon reduction is also proposed.

State of the Art: Built facilities consume over 40% of global energy annually resulting in over 33% of world's total carbon emission. According to literature, for a significant reduction in energy use and resulting carbon emissions, it is critical that both the embodied and operating energy use of a facility is optimized.

Approach: A literature-based discovery approach was applied to collect, analyze, and synthesize the results of published case studies from around the globe. The energy use results of 158 published case studies were analyzed to derive conclusions.

Results: A comparison of energy efficient and conventional facilities revealed that decreasing operating energy may increase the embodied energy components. Additionally, the analysis of 95 commercial facilities indicated that nearly 10% of the total U.S. carbon emissions was influenced by facilities management practices.

Practical Implications: The proposed approach to holistic environmental footprint reduction can guide facility management research and practice to make meaningful contributions to our efforts for creating a sustainable built environment.

Research Limitations: The results were derived from case studies that belonged to various locations across the globe and included facilities constructed with a variety of materials.

Originality/Value: This paper quantifies the extent to which a facilities management professional can contribute to the global efforts of reducing carbon emission.

Keywords: Facility Management, Embodied energy, Recurring energy, Carbon emission

1 INTRODUCTION

Looking at the current environmental conditions and the amount of resource use, we may not be able to completely avert the global warming, no matter in what amount we now try to reduce the carbon emission (Hacker et al., 2008). The major cause of Earth's warming is anthropogenic greenhouse gas emission, particularly the emission of carbon dioxide, methane, and nitrous oxide (Hacker et al., 2008; USEPA, 2011). Nearly 95% of the total global carbon emissions can be attributed to fossil fuel combustion as a result of electricity production, transportation, residential and commercial operations, and the manufacturing industry (USEPA, 2011). A majority of carbon dioxide emission is the result of consuming energy sources such as electricity, petroleum, natural gas, and coal, but according to the U.S. Greenhouse Gas Emission Report (USEPA, 2011), the electricity generation alone was responsible for nearly 42% of the total U.S. carbon dioxide emissions in 2009.

The building sector consumes over 40% of global energy annually in the construction, use, maintenance, and the demolition of buildings (Dixit et al., 2012a). Both the primary (e.g., coal, petroleum) and delivered energy (e.g., electricity, gasoline, and natural gas) are used directly or indirectly (Marszal et al., 2010; Dixit et al., 2013). The total life cycle energy (LCE) consumed by a facility is made of two components: life cycle embodied energy (LCEE) and operating energy (OE). The relative proportion of embodied and operating energy in a facility's life cycle has been debated in the literature (Dixit et al., 2012a). However, the literature agrees on the fact that, for a significant reduction in energy use and resulting carbon emissions, the consumption of both the embodied and operating energy needs to be reduced (Brown and Pit, 2001; Elmualim et al., 2010). Facilities management practices can significantly impact the energy and environmental footprint of a facility (Jensen and Neilsen, 2008; Elmualim et al., 2010; Dixit et al., 2014). For instance, decisions regarding facility maintenance, replacement, renovation, capital renewal, retrofit, and demolition can affect the total LCEE and OE (Dixit et al., 2014; Elmualim et al., 2010). Issues of human comfort, user satisfaction, and operating costs relate to the life cycle operating energy, which is one of the major domains of facilities management (Jensen and Neilsen, 2008; Elmualim et al., 2010).

The main purpose of this paper is to highlight the importance of adopting a life cycle perspective for evaluating an energy-efficient and carbon neutral building. In addition, the impact of facility management practices in reducing the life cycle carbon footprint of built facilities is emphasized. We also examine the case studies of energy efficient facilities to investigate the savings of LCEE and OE over facilities' life cycle.

2 STATE OF THE ART

2.1 Carbon Emission from Built Facilities

The building sector is responsible for 33% of the total annual carbon emission of the world (Marszal et al., 2010). In the United States, building stocks alone cause 39% of the total annual carbon dioxide emission (USEPA, 2009). According to Levermore (2008), the commercial building-related carbon emission grew by 2.2% annually across the globe between 1971 and 2002. By the end of 2030, building-related carbon emission would increase by 72% from its 2002 levels, projections state.

Most of the carbon emission originates from electricity and primary energy use. The 2002 Economic Census (USCB, 2005) reported a 130% rise in electricity use and 23% in natural gas use by the U.S. construction industry between 2002 and 2007. As reported by the 2011 Annual Energy Review (USDOE, 2012a), over 40% of the total United States' energy supply was consumed by the residential and commercial sector. A majority of this energy supply (more than 80%) came from the fossil fuel-based sources. Because the electric power sector still remains the biggest contributor to the nation's total carbon dioxide emissions (33-34%), any increase in electrical demand would raise carbon emissions proportionally (USEPA, 2013). For instance, in 2006, a 2.5% increase in electricity demand resulted in a 3% increase in carbon dioxide emissions from the electric power sector (USDOE, 2008).

2.2 Energy Consumption Model for Built Facilities

Built facilities use both the primary and delivered energy in their life cycle stages of production, operation, maintenance, and demolition (Dixit et al., 2010). The total energy consumed in constructing a facility is known as initial embodied energy (IEE) (Vukotic et al., 2010; Dixit et al., 2013). This energy is embedded in products (e.g., materials, assemblies, and equipment) and processes (e.g., construction, transportation, and administration) used in the construction of the facility. When the facility is occupied and used, products and processes are consumed in the activities of maintenance, replacement, and retrofit. The energy embodied in these products and processes is known as recurrent embodied energy (REE) (Vukotic et al., 2010; Dixit et al., 2013). When the facility is demolished and its materials are sorted for recycling, reuse, or disposal, the energy consumed in such activities is called demolition energy (DE). The sum of IEE, REE, and DE is termed the life cycle embodied energy (LCEE). The fraction of life cycle energy used in operating a facility in the processes of air-conditioning, heating, lighting, and powering facility's appliances is known as operating energy (OE) (Vukotic et al., 2010). The sum of total LCEE and OE is termed the total life cycle energy (LCE). According to literature, for a significant reduction in the environmental footprint of built facilities, a life cycle energy and carbon accounting is important that takes into account both the LCEE and OE (Aste et al., 2010).

The percentage of embodied energy in a building's life cycle depends upon the building's location, climate, and fuel sources used (Nebel et al., 2011). Low-energy buildings have a relatively higher fraction of life cycle energy use as embodied energy than the conventional buildings. This is due to the fact that low energy buildings consume less operating energy and may contain building materials such as insulation that hold higher embodied energy.

2.3 Facility Management and Life Cycle Environmental Analysis

The field of facility management affects all three dimensions of sustainability: economics (life cycle cost), environment (energy and emissions), and society (user satisfaction and productivity) (Ashford, 2004). The consumption of resources, particularly during the use

phase of a facility, such as building materials, energy sources, water, and labor, mainly depends on a facility manager's maintenance and replacement planning and scheduling (Brown and Pitt, 2001; Elmualim et al., 2010). Building systems such as HVAC, hot water, lighting, and building appliances consume a significant amount of energy that can be decreased by effective facility management. In a study of educational facilities, Cash and Twiford (2009) found that a typical school in the United States consumed nearly 55% of its annual energy on space conditioning and 30% on lighting. This means that approximately 85% of the total annual energy use was under the control of a facility manager. Energy consumption, pollution, and resource consumption are the primary aspects of environmental efficiency that connect facility management to sustainability (Brown and Pitt, 2001). For creating a truly energy efficient built facility, both the embodied and operating energy should be optimized (Brown and Pitt, 2001; Elmualim et al., 2010).

3 APPROACH

The main goal of this paper is to emphasize the importance of a life cycle perspective when evaluating a facility for energy efficiency and carbon emission. Due to a focus on a facility's life cycle, the paper also highlights the importance of facility management practices in reducing the life cycle energy and carbon impacts of constructing, operating, maintaining, and demolishing facilities. This goal can be achieved by the following objectives:

- Investigate the OE and LCEE savings of energy efficient facilities
- Quantify relative share of LCEE and OE in the total LCE of commercial facilities
- Determine the extent to which facility management practices influence the LCEE and OE

A "Literature Based Discovery (LBD)" method was applied that derives conclusions from the review of published data. Although LBD was originally established to be used for biomedical science research, it has been successfully applied to other disciplines also (Weeber et al., 2001; Dixit et al., 2010). A rigorous survey of literature was performed to select only studies which calculated the LCE including the three major components, IEE, REE, and OE. A total of 158 residential and commercial case studies were referred from across the globe (see Table1).

Table 1: List of the referred case studies

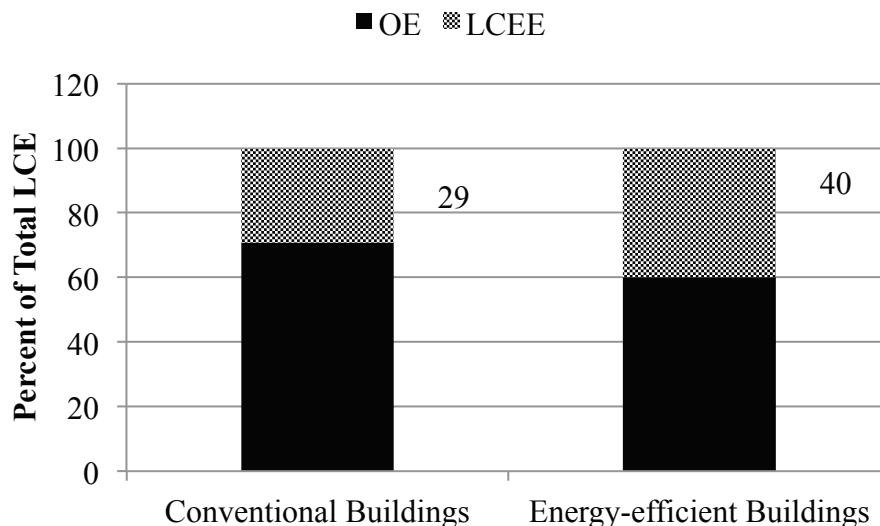
Study	Location	Study	Location
Treloar, 1993	Australia	Thormark, 2002	Sweden
Barnes and Rankin, 1995	United Kingdom	Citherlet and Hand, 2002	Switzerland
Cole and Kernan, 1996	Canada	Scheuer, 2003	United States
Kernan, 1996	Canada	Lippke et al., 2004	United States
Jaques, 1996	New Zealand	Winistorfer et al., 2005	United States
Adalberth, 1997	Sweden	Randolph et al., 2006	Australia
Kohler et al., 1997	Switzerland	Thormark, 2006	Sweden
Blanchard and Reppe, 1998	United States	Junnla et al., 2006	Finland
Fay and Treloar, 1998	Australia	Page, 2006	New Zealand
Eaton et al., 1998	United Kingdom	Thormark, 2007	Sweden
Suzuki and Oka, 1998	Japan	Citherlet and Defaux, 2007	Switzerland
Newton et al., 2000	Australia	Ding, 2007	Australia
Fay et al., 2000a	Australia	Langston and Langston, 2007	Australia
Fay et al., 2000b	Australia	Fernandez, 2008	New Zealand
Pullen, 2000	Australia	John et al., 2009	New Zealand
Johnstone et al., 2001	New Zealand	Shen, 2010	China
Treloar et al., 2001	Australia	Leckner and Zmeureanu, 2011	Canada

As some of the studies included apartments and houses, only commercial facilities (95 case studies) were included for investigating the significance of facilities management in reducing the environmental footprint. The case studies were categorized as energy-efficient and conventional buildings on the basis of definitions given by the referred studies. Because the amount of the total REE and OE depends on the service life of a facility, the embodied energy results are presented in annual mega joules per unit area ($\text{MJ}/\text{m}^2\text{-year}$). To calculate the amount of carbon emission resulting from fossil fuel consumption, an average value of carbon dioxide emission coefficient was calculated using the values provided by the Energy Information Administration website (USEIA, 2013). It was assumed that the energy values are reported in primary energy units.

4 RESULTS

An analysis of the results of referred energy efficient and conventional buildings revealed that optimizing a facility's life cycle OE could mean an increase in its LCEE. Figure 1 shows the fraction of OE and LCEE in the average value of the total LCE of energy efficient and conventional buildings. As seen in Figure 1, the fraction of LCEE increased in the case of energy efficient buildings due to a decrease in OE; however, even though the OE was reduced, this was at the cost of LCEE. Table 2 lists the values of OE and LCE of some of the case studies for base case (cells marked with grey shades) and energy efficient case. The fact that reducing OE could significantly increase a facility's LCEE highlight the significance of a whole life cycle energy accounting in designing and evaluating energy efficient facilities.

Figure 1: LCEE and OE fraction in the total LCE of referred case studies



Based on the results reported by the referred case studies of commercial facilities, the average value of the total annual LCE is calculated as $1222.26 \text{ MJ}/\text{m}^2\text{-year}$. The reported values of LCE range from $200\text{--}2841.71 \text{ MJ}/\text{m}^2\text{-year}$. The fraction of the total LCEE and OE in the total LCE is found as 76.6% ($285.60 \text{ MJ}/\text{m}^2\text{-year}$) and 23.4% ($936.66 \text{ MJ}/\text{m}^2\text{-year}$), respectively. Figure 2 illustrates the various life cycle energy components as reported by the referred case studies. As seen in Figure 2, the embodied energy components such as IEE, REE, and DE account for up to 11.45%, 11.86%, and 0.06% of the total LCE, respectively.

Table 2: Increase in LCEE due to energy efficient measures

Study	OE (GJ/m ²)	LCEE (GJ/m ²)	LCE (GJ/m ²)	% LCEE Increase Over Base Case
Feist, 1996	9.5	4.37	13.87	0.00%
Feist, 1996	4.32	5.01	9.33	14.65%
Feist, 1996	0	9.91	9.91	126.77%
Winther and Hestnes, 1999	23.7	2	25.7	0.00%
Winther and Hestnes, 1999	11.4	4.5	15.9	125.00%
Karlsson and Moshfegh, 2007	25.56	5.08	30.64	0.00%
Karlsson and Moshfegh, 2007	11.25	7.03	18.28	38.39%

Figure 2: Average values of embodied and operating energy components

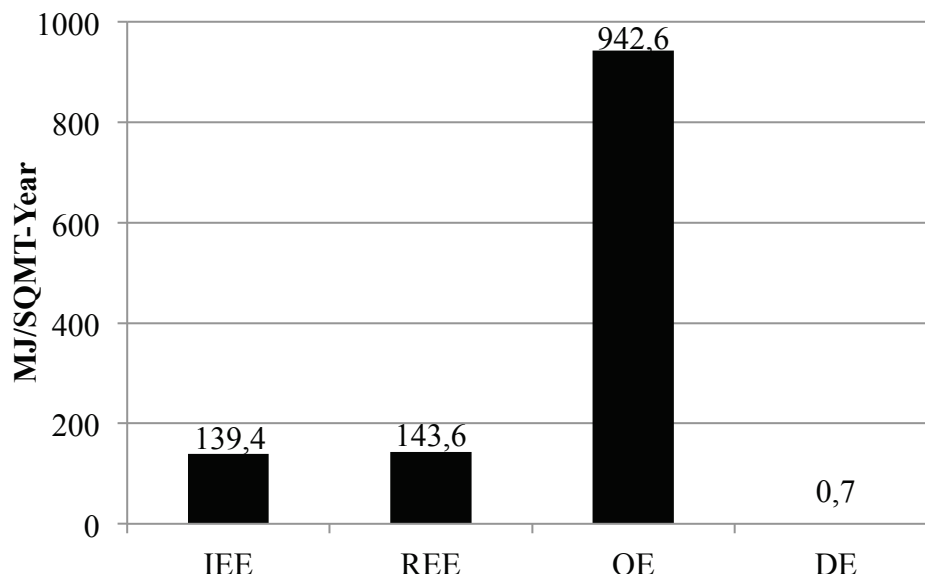
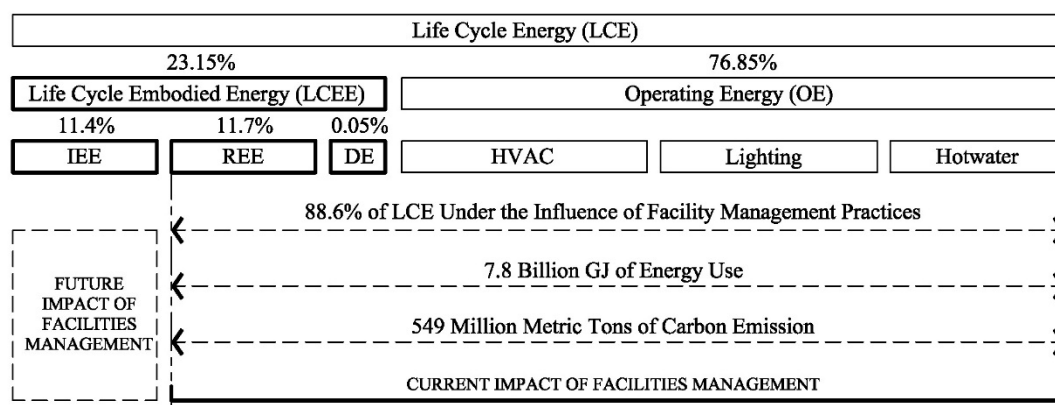


Figure 3 illustrates the impact of facilities management on the life cycle energy components.

Figure 3: Influence of facilities management over the environmental footprint of facilities



As shown in Figure 3, the facilities management practices related to a facility's operation and maintenance could impact at least 88.6% (sum of OE, REE, and DE) of the total LCE. If

facility managers are involved in the pre-design, design, and construction phases, their decisions about material and product selection may impact more than 90% of the LCE. Since the values of various LCE components are calculated per unit area, the total commercial floor space can be used to quantify the total energy and environmental impacts at a national level. The Building Energy Data Book (USDOE, 2012b) reported a total commercial floor area of 81.1 billion ft² in the United States for year 2010. Furthermore, it was projected to reach 103 billion ft² by the end of 2035. Considering the total commercial floor space in 2010, 88.6% of the total LCE would represent approximately 8.2 billion gigajoules (7.8 quadrillion Btu) of primary energy. This energy use would be nearly 10% of the total national fossil fuel consumption in 2010. Using the average carbon dioxide emission coefficient (70.7 kg per million Btu) from the USDOE website, this energy use could result in approximately 549 million metric tons of carbon dioxide released to the atmosphere. According to the Building Energy Data Book (USDOE, 2012b), by the end of 2035, this energy use and resulting carbon dioxide emission would reach approximately 10.4 billion gigajoules and 698 million metric tons, respectively.

Decisions such as physical repair and selection of products for a facility's maintenance and replacement activities significantly affect its REE and OE. In terms of the environmental impacts, such decisions could influence up to 550 million metric tons of carbon emissions. According to the 2011 Annual Energy Review, the total amount of carbon dioxide emitted as a result of energy-related use in 2010 was approximately 5.6 billion metric ton; therefore, nearly 10% of the total national carbon dioxide emission could be influenced by facilities management practices of commercial buildings. If residential buildings were included, this percentage could increase significantly.

5 PRACTICAL IMPLICATIONS

The results of this study indicate the importance of facilities management professionals in creating an energy efficient and carbon neutral built environment. For a comprehensive reduction in the environmental footprint of buildings, both the embodied and operating energy needs to be reduced. The practical implications of this study are manifold.

First, the research findings could encourage facility management professionals to adopt a whole life cycle-based approach while selecting a low energy building material or equipment. Because the amount of REE significantly influences a facility's total LCEE, selecting durable and recyclable materials with low embodied energy, long service life, and low maintenance requirements can significantly reduce its environmental footprint. Similarly, since the embodied energy is greatly impacted by transportation modes and distances, using locally available resources, a facility manager can help reduce the overall LCEE. According to Thormark (2006), approximately 17% of the total LCEE can be optimized by making such environmental choices of building materials. As seen in Table 3, significant amount of REE can be saved if number of replacements over a facility's service life is reduced.

Table 3: REE of each replacement (Based on Pullen, 2000; Junnila et al., 2006; Jaques, 1996)

Replacement Item	REE (GJ/Replacement)	Replacement Item	REE (GJ/Replacement)
Painting	787-5320	Carpet	1564-4573
Roof Cladding	5050	Retile PVC Floor/Vinyl	740-2362
Doors and fitments	2920	Services (50%)	14115

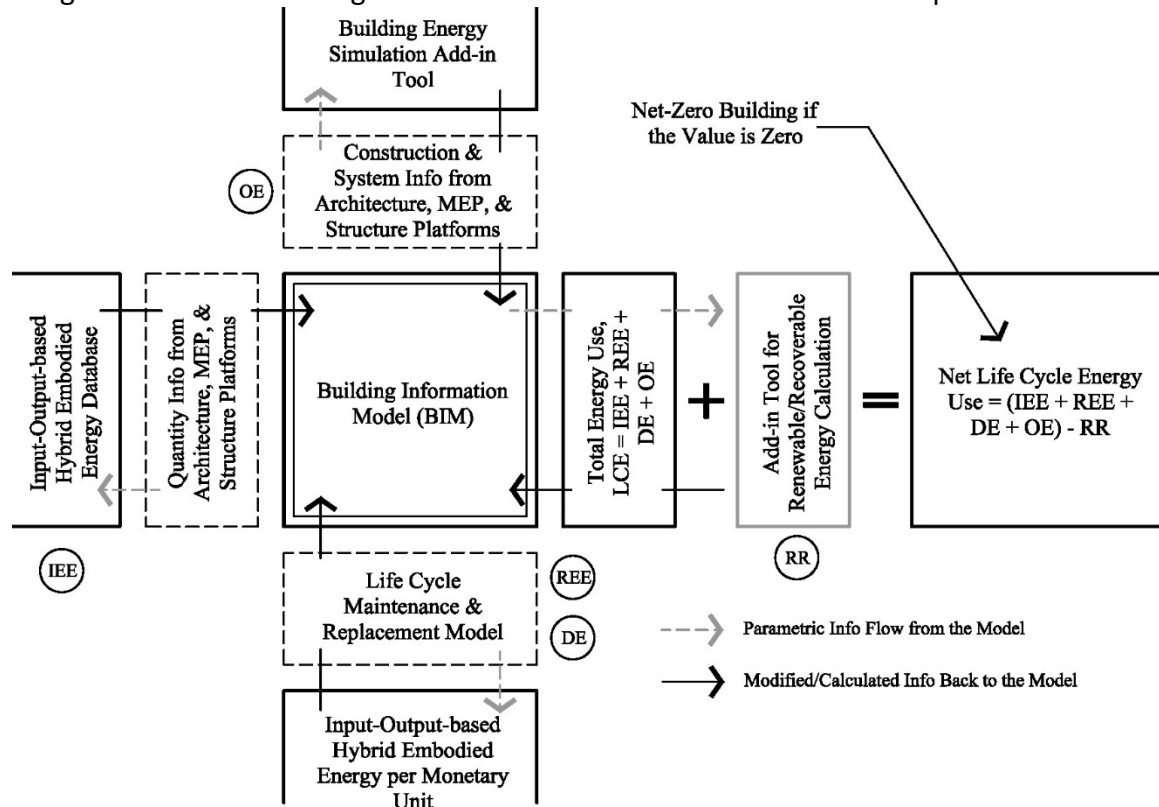
Second, since facility managers are responsible for building system operation and maintenance, a significant reduction in OE use can be achieved using strategies such as daylighting, retro-commissioning, and continuous commissioning. For instance, according to Claridge et al. (2009), by using the process of continuous commissioning, approximately 24% of the energy cost of a facility's HVAC system can be saved. By upgrading technologies and operators' skills, facility managers can reduce facility energy use (Jensen and Nielsen, 2008).

Third, selecting durable materials and equipment with low maintenance and replacement requirements could also generate monetary savings making the facility economically sustainable. Fourth, with a life cycle-based approach, informed decisions could be made on whether to renovate or demolish and reconstruct a particular facility. Finally, this study underscores the importance of involving facility management professionals in the early design stages, because design decisions affect most of the energy and environmental footprint of a building. If a facility management professional is involved during a facility's design and construction phases, durable and recyclable materials, assemblies, and equipment with low environmental impacts and long service life could be selected. Involving facility managers would also ensure selecting materials suitable for a particular building function.

5.1 Model to Reduce Environmental Footprint of Built Facilities

The findings of this study indicate a need to establish a system that helps evaluate a facility's environmental performance over its life cycle. We recommend developing tools and databases and integrating them to a technology such as Building Information Modeling or BIM widely accepted by facility design, construction, and management professionals. Figure 4 illustrates a model that can be applied to a BIM platform (e.g. Revit Architecture) for a life cycle energy and carbon evaluation.

Figure 4: Facilities management model to reduce environmental footprint of facilities



As seen in Figure 4, three add-in tools can be integrated into a BIM platform. The first tool extracts the material, equipment, and climate information from BIM to evaluate a facility's operating energy performance. Such efforts to integrate thermal load simulation are already underway (e.g. Yan et al., 2013). Second tool uses the life cycle embodied energy database of building materials, assemblies, products (e.g. furniture), and equipment to quantify the life cycle embodied impacts of initial construction using the material quantities from BIM. To quantify the REE, a life cycle cost model can be connected to BIM. For calculating the renewable energy generation, a separate application can be developed as explained by Dixit et al. (2012b). This model can facilitate the development of a single, user-friendly, and widely accepted tool to facility designers, constructors, and managers for calculating, analyzing, and reducing the life cycle energy and environmental impacts of a facility.

6 CONCLUSIONS

The results of referred case studies revealed that designing an energy efficient facility by only reducing its OE may not be the optimum solution to the skyrocketing carbon emissions from the building sector. An energy efficient facility should be designed based on a holistic energy accounting of the initial energy spent in its design and construction (embodied energy); the energy consumed in operating, maintaining, and renovating the facility; and the amount of renewable energy it can generate over its life cycle. Based on the net energy consumed or generated, the facility can be labeled energy efficient or energy independent. A review of commercial facilities concluded that the field of facility management could impact up to 89% of a facility's operating and embodied energy use. This is significant, for it represents up to 10% of the United States' annual carbon emission.

REFERENCES

- Adalberth, K. (1997), "Energy use during the life cycle of single-unit dwellings: examples," *Building and Environment*, 32, 4, 321-329.
- Ashford, N.A. (2004), "Major challenges to engineering education for sustainable development, what has to change to make it creative, effective, and acceptable to the established disciplines?," *International Journal of Sustainability in Higher Education*, 5, 3, 239-250.
- Aste, N., Adhikari, R. S., and Buzzetti, M. (2010), "Beyond the EPBD: the low energy residential settlement Borgo Solare," *Applied Energy*, 87, 2, 629-642.
- Barnes, D., and Rankin, L. (1975), "The energy economics of building construction," *Building International*, 8, 31-42.
- Blanchard, S., and Reppe, P. (1998), *Life cycle analysis of a residential home in Michigan*, Center for Sustainable Systems, University of Michigan, USA.
- Brown, A.W., and Pitt, M.R. (2001), "Measuring the facilities management influence in delivering sustainable airport development and expansion," *Facilities*, 19, 5/6, 222-232.
- Cash, C., and Twiford, T. (2009), Improving student achievement and school facilities in a time of limited funding, Retrieved on 12 January 2012 from <http://cnx.org/content/m23100/latest/>.
- Citherlet, S., and Defaux, T. (2007), "Energy and environmental comparison of three variants of a family house during its whole life span," *Building and Environment*, 42, 2, 591-598.

- Citherlet, S., and Hand, J. (2002), "Assessing energy, lighting, room acoustics, occupant comfort and environmental impacts performance of building with a single simulation program," *Building and Environment*, 37, 8/9, 845-856.
- Claridge, D. E., Turner, W. D., Liu, M., Deng, S., Wei, G., Culp, C., ... and Cho, S. (2004), "Is Commissioning Once Enough?," *Energy Engineering*, 101, 4, 7-19.
- Cole, R.J., and Kernan, P.C. (1996), "Life-cycle energy use in office buildings," *Building and Environment*, 31, 4, 307-317.
- Ding, G.K.C. (2007), "Life cycle energy assessment of Australian secondary schools," *Building Research and Information*, 35, 5, 487-500.
- Dixit, M.K., Culp, C. H., and Fernández-Solís, J. L. (2013), "System boundary for embodied energy in buildings: A conceptual model for definition," *Renewable and Sustainable Energy Reviews*, 21, 153-164.
- Dixit, M.K., Culp, C.H., Lavy, S., and Fernández-Solís, J.L. (2014), "Recurrent embodied energy in life cycle of built facilities," *Facilities*, accepted for publication.
- Dixit, M.K., Fernández-Solís, J. L., Lavy, S., and Culp, C. H. (2012a), "Need for an embodied energy measurement protocol for buildings: A review paper," *Renewable and Sustainable Energy Reviews*, 16, 6, 3730-3743.
- Dixit, M.K., Fernández-Solís, J., Lavy, S., and Culp, C.H. (2010), "Identification of parameters for embodied energy measurement: A literature review," *Energy and Buildings*, 42, 8, 1238-1247.
- Dixit, M. K., and Yan, W. (2012b), "BIPV prototype for the solar insolation calculation," *Gerontechnology*, 11(2), 162.
- Eaton, K.J., Gorgolewski, M., Amato, A., and Birtles, T. (1998), "Using Life Cycle Assessment as a Tool for Quantifying Green Buildings," in *Proceedings of the international conference on steel in green building construction*, 1998, Orlando, USA.
- Elmualim, A., Shockley, D., Valle, R., Ludlow, G., and Shah, S. (2000), "Barriers and commitment of facilities management profession to the sustainability agenda," *Building and Environment*, 45, 1, 58-64.
- Fay, R., and Treloar, G. (1998), "Life cycle energy analysis – a measure of the environmental impact of buildings," *Environment Design Guide*, 22, 1-7.
- Fay, R., Treloar, G., and Iyer-Raniga, U. (2000a), "Life-cycle energy analysis of buildings: a case study," *Building Research & Information*, 28, 1, 31-41.
- Fay, R., Vale, R., and Vale, B. (2000b), "Assessing the importance of design decisions on life cycle energy and environmental impact," in Steemers, K, Yannas, S (Ed.), *Proceedings of PLEA 2000*, July 2000, Cambridge, United Kingdom, pp. 164-169.
- Feist, W. (1996), "Life-cycle energy balances compared: low-energy house, passive house, self-sufficient house," In *Proceedings, Tagungsbericht : energy and mass: 1996 International Symposium of CIB W67*, 4-10 August, 1996, pp. 183-190.
- Fernandez, N.P. (2008), "The influence of construction materials on life cycle energy use and carbon dioxide emissions of medium size commercial buildings," Ph.D. Thesis, School of Architecture, Victoria University of Wellington, Wellington, New Zealand.
- Hacker, J. N., De Saulles, T. P., Minson, A. J., and Holmes, M. J. (2008), "Embodied and operational carbon dioxide emissions from housing: a case study on the effects of thermal mass and climate change," *Energy and Buildings*, 40, 3, 375-384.
- Jaques, R. (1996), "Energy efficiency building standards project - review of embodied energy," in Treloar et al. (Ed.), *Proceedings of embodied energy seminar: current state of play*, November 28-29, 1996, Deakin University, Geelong, Australia.

- Jensen, P.A., and Nielsen, S.B. (2008), "Sustainable FM-a new field of research and practice," *Design Manager*, Netherlands, Retrieved from on 7 December 2010 <http://orbit.dtu.dk/getResource?recordId=231677&objectId=1&versionId=1>
- John, S., Nebel, B., Perez, N., and Buchanan, A. (2009), "Environmental impacts of multi-storey buildings using different construction materials," Research Report 2008-02, University of Canterbury, New Zealand.
- Johnstone, I.M. (2001), "Energy and mass flows of housing: a model and example," *Building and Environment*, 36, 1, 27-41.
- Junnala, S., Horvath, A., and Guggemos, A.A. (2006), "Life-cycle assessment of office buildings in Europe and the United States," *Journal of Infrastructure Systems*, 12, 1, 10-17.
- Karlsson, J. F., and Moshfegh, B. (2007), A comprehensive investigation of a low-energy building in Sweden, *Renewable energy*, 32, 11, 1830-1841.
- Kernan, P.C. (1996), "Life cycle energy analysis of an office building," MS Thesis, School of Architecture, The University of British Columbia, Vancouver, Canada.
- Kohler, K., Klingele, M., Heitz, S., Hermann, M., and Koch, M. (1997), "Simulation of energy and massflows of buildings during their life cycle," in *CIB Second International Conference on Buildings and the Environment*, 1997, Paris.
- Langston, Y.L., and Langston, C.A. (2007), "Building energy and cost performance: An analysis of 30 Melbourne Case Studies," *Australian Journal of Construction Economics and Buildings*, 7, 1, 1-18.
- Leckner, M., and Zmeureanu, R. (2011), "Life cycle cost and energy analysis of a Net Zero Energy House with solar Combisystem", *Applied Energy*, 88, 1, 232-241.
- Levermore, G. J. (2008), "A review of the IPCC assessment report four, part 1: the IPCC process and greenhouse gas emission trends from buildings worldwide," *Building Services Engineering Research and Technology*, 29, 4, 349-361.
- Lippke, B., Wilson, J., Perez-Garcia, J., Bowyer, J., and Meil, J. (2004). "CORRIM: Life-cycle environmental performance of renewable building materials," *Forest Products Journal*, 54, 6, 8-19.
- Marszal, A. J., Bourrelle, J. S., Musall, E., Heiselberg, P., Gustavsen, A., and Voss, K. (2010), "Net zero energy buildings-calculation methodologies versus national building codes," In EuroSun Conference, Graz, Austria.
- Nebel, B., Alcorn, A., Wittstock, B. (2011), *Life cycle assessment: adopting and adapting overseas LCA data and methodologies for building materials in New Zealand*, New Zealand: Ministry of Agriculture and Forestry.
- Newton, P., Tucker, S., and Ambrose, M. (2000), "Housing form, energy use and greenhouse gas emission," in Williams et al. (Ed.), *Achieving sustainable urban form*, SPON Press, London.
- Page, I. (2006), *Timber in Government buildings - cost and environmental impact analysis*, E408, Project No. QC 5018, BRANZ Limited, New Zealand.
- Pullen, S. (2000), "Energy assessment of institutional buildings," in *Proceedings of ANZAScA*, 1-3 December 2000, University of Adelaide, Adelaide, Australia.
- Randolph, B., Holloway, D., Pullen, S., and Troy, P. (2006), *The environmental impacts of residential development: case studies of 12 estates in Sydney*, Project LP 0348770. City Futures Research Centre, University of New South Wales, Kensington, Australia.
- Scheuer, C., Keoleian, G.A., and Reppe, P. (2003), "Life cycle energy and environmental performance of a new university building: Modeling changes and design implications," *Energy and Buildings*, 35, 10, 1049-1064.

- Shen, S., Vale, R., and Vale, B. (2010), *The life-cycle environmental impact of exhibition buildings: a case study*, in *Melbourne 2010 Knowledge Cities World Summit*, 16-19 November 2010, Melbourne, Australia.
- Suzuki, M., and Oka, T. (1998), "Estimation of life cycle energy consumption and CO₂ emission of office buildings in Japan," *Energy and Buildings*, 28, 1, 33-41.
- Thormark, C. (2002), "A low energy building in a life cycle - Its embodied energy, energy for operation and recycling potential," *Building and Environment*, 37, 4, 429-435.
- Thormark, C. (2007), "Energy and resources, material choice and recycling potential in low energy buildings," in *CIB Conference, SB 07 Sustainable Construction Materials and Practices*, 2007, Lisbon, Portugal.
- Thormark, C. (2006), "The effect of material choice on the total energy need and recycling potential of a building," *Building and Environment*, 41, 8, 1019-1026.
- Treloar, G.J. (1993), "Embodied energy analysis of buildings Part 2: A case study," *Exedra*, 4, 1, 11-13.
- Treloar, G.J., Love, P.D.E., and Faniran, O.O. (2001), "Improving the reliability of embodied energy methods for project life-cycle decision making," *Logistics Information Management*, 14, 5/6, 303-317.
- USCB (2005), *2002 Economic Census, Construction, Industry Series*, United States Census Bureau, Washington, D.C.
- USEIA (2013), Carbon Dioxide Emissions Coefficients, retrieved on 30 October 2013 from http://www.eia.gov/environment/emissions/co2_vol_mass.cfm
- USDOE (2008), *Emissions of greenhouse gases in the United States 2007*, DOE/EIA-0573 (2007), December 2008, U.S. Department of Energy, Washington, D.C.
- USDOE (2012a), *Annual Energy Review 2011*. DOE/EIA-0.384 (2011), September 2012, Energy Information Administration, U.S. Department of Energy, Washington, D.C.
- USDOE (2012b), *2011 Building Energy Data Book*, March 2012, Buildings Technologies Program, U.S. Department of Energy, Washington, D.C.
- USEPA (2009), *Buildings and their Impact on the Environment: A Statistical Summary*, United States Environmental Protection Agency, Washington, D.C.
- USEPA (2011), *Inventory of U.S. greenhouse gas emissions and sinks: 1990-2009*, EPA 430-R-11-005, April 15 2011, U.S. Environmental Protection Agency, Washington, D.C.
- USEPA (2013), *Inventory of U.S. greenhouse gas emissions and sinks: 1990-2011*, EPA 430-R-13-001, April 12 2013, U.S. Environmental Protection Agency, Washington, D.C.
- Vukotic, L., Fenner, R.A., and Symons, K. (2010), "Assessing embodied energy of building structural elements," *Engineering Sustainability*, 163, ES3, 147-158.
- Weeber, M., Klein, H., de Jong-van den Berg, L., and Vos, R. (2001), "Using concepts in literature-based discovery: Simulating Swanson's Raynaud-fish oil and migraine-magnesium discoveries," *Journal of the American Society for Information Science and Technology*, 52(7), 548-557.
- Winistorfer, P., Chen, Z., Lippke, B., and Stevens, N. (2005), "Energy consumption and greenhouse gas emissions related to the use, maintenance, and disposal of a residential structure," *Wood and Fiber Science*, 37(sp. Issue), 128-139.
- Winther, B. N., and Hestnes, A. G. (1999), "Solar versus green: the analysis of a Norwegian row house," *Solar Energy*, 66, 6, 387-393.
- Yan, W., Clayton, M., Haberl, J., Jeong, W., Kim, J. B., Kota, S., ... and Dixit, M. Interfacing BIM With Building Thermal And Daylighting Modeling, in *Proceedings of BS2013*, Chambery, France, 26-28 August 2013.

6.3

ASSESSING THE ENERGY EFFICIENCIES OF INDIVIDUAL DEPARTMENTS WITHIN UNIVERSITIES WITH THE 'DEA ENERGY MANAGEMENT SYSTEM': AN EMPIRICAL STUDY

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ABSTRACT

Purpose: Adopts two research concepts, i.e. 'space type' and 'internal benchmark', as and the 'data envelopment analysis (DEA)' method to establish the 'DEA Energy Management System (DEMS)' to assist individual departments within universities in their energy management tasks.

Background: Individual buildings within university campuses are often occupied by different departments in Taiwan, which has created a great challenge to the energy management task.

Approach: The proposed DEMS considers each 'space' within a department in a given 'time' (such as a month) as a decision making unit (DMU). Then, regression analysis is performed on data of 'existing environment', 'occupancy' factors, and 'actual energy consumption EUI (energy usage intensity)' related variables. The regression equation derived is then used to calculate the 'predicted EUI' for all DMUs. The 'actual EUI' is further considered as the input data, and the 'predicted EUI' as the output data of the DEMS, on which data envelopment analysis is conducted to produce three types of energy efficiency scores (overall efficiency, scale efficiency, pure technical efficiency) to indicate the energy efficiencies of all DMUs.

Results: The DEMS was further implemented in the Department of Architecture of NTUST in Taiwan to illustrate how it can be used to assist individual departments within universities in assessing the energy management effectiveness of their spaces.

Practical implications: The DEMS allows facility managers to assess and compare the energy efficiency scores 'among different spaces', to further review the energy efficiency of a space 'over time'; and to recognize the benchmark cases and pursue actions for energy improvement.

Research limitations: The accuracy of the energy efficiency scores depends greatly on the accuracy of the predicted EUIs of spaces and therefore it is critical to identify a better regression model with higher predictability (R^2). The relatively low actual EUIs of certain student spaces during winter and summer breaks may greatly affect the resulting energy efficiency scores.

Originality/value: This study explores the research concepts of 'space type' and 'internal benchmark' with an analytical method 'data envelopment analysis' to assess the energy efficiency of an individual department which may only occupy certain floors of a building.

Keywords: Space type, Internal benchmark, Existing environment factors, Occupancy factors, Energy management effectiveness

1 INTRODUCTION

1.1 Background

'Energy management' has become an important facility management issue for universities in Taiwan. Individual departments within universities are usually held responsible for managing the energy efficiency of their facilities. This becomes a challenging task when several departments occupy the same facility and that individual departments lack reasonable energy consumption benchmarks or indices. Although Taiwan government has issued average EUI (energy usage intensity, Wh/m²) indicators for universities as energy benchmarks, these indicators are unable to assist facility managers in further assessing the energy efficiencies of their facilities, spotting the over-consumed areas, and identifying the directions of energy management (Tu and Lin, 2012). As a result, the average EUI indicators are not as effective for 'energy management' purpose.

Within the same building (same 'existing environment' conditions), two departments with different 'occupancy' needs are likely to consume different amount of energy, and it will be unreasonable to say that the department consuming less energy is more energy efficient than the other. This study thus argues that it is critical to take into account the 'management' factors while assessing the energy efficiencies of individual departments within universities. For effective energy management, individual departments are in great need of a tool capable of first assessing their energy efficiencies from 'management' perspective to identify problem areas and improvement plans exhibiting immediate energy saving effects, before any other expensive energy saving measures such as building renovations are taken.

To assist individual departments in their complex energy management tasks, this study adopts the research concepts of 'space type' and 'internal benchmark' proposed by Tu and Lin (2012). The concept of 'space type' allows us to explicitly observe and distinguish the effects of 'occupancy use patterns' on energy consumptions among different space types. When a standard energy consumption can be identified for each space type, then the standards energy consumptions of all space types can be aggregated as the 'internal benchmark', which becomes a reasonable energy references for individual departments.

The data envelopment analysis (DEA) has been generally used in the performance assessment of resource usage. In the field of building energy management, it has been adopted to assess the energy efficiencies of several building types, such as hotels (Önüt and Soner, 2006), commercial buildings (Chung et al., 2006) and school buildings (Filippin, 2000). This study believes that it is applicable to energy efficiency assessment of various 'space types' within individual departments.

1.2 Research Objectives

Can the DEA method be applied in establishing internal energy efficiency benchmarks for individual departments within universities? What are the potentials and limitations of its applications? To answer the above questions, this study adopts the 'space type' and 'internal benchmark' research concepts, and to explore the 'Data Envelopment Analysis (DEA)' method in establishing the 'DEA Energy Management System (DEMS)' to assist individual departments within universities in assessing the energy efficiencies of their facilities from the 'management' perspective. The DEMS is further applied in assessing the energy management effectiveness of an empirical case within a national university in Taiwan in order to demonstrate the analytical procedures and assessment results, and to discuss the potential and the limitations of the DEMS.

2 LITERATURE REVIEW: ENERGY EFFICIENCY ASSESSMENT METHODS

This study has reviewed the existing literature focusing on the energy management aspects of 'existing buildings' and categorized them into two groups based on their research objectives. The first group involved diagnosing the energy efficiency of a 'building or system', proposing improvement plans (such as installing external shading devices), and employing energy simulation software to assess the magnitude of energy savings achieved by various plans (Hatamipour et al., 2007). The approaches taken often involve in-depth investigation and large scale refurbishment, and incur high costs. They thus are not useful for departments in universities, who simply need a tool to perform preliminary evaluation on the energy efficiency of their facilities and to identify problem areas first.

The second group of studies typically involved developing energy efficiency scales or evaluation methods to measure and compare the energy efficiencies of various buildings. For example, in Hong Kong, the Building Environmental Assessment Method (HK-BEAM) was developed to measure the energy performance of buildings against the 'baseline building' (Lee et al., 2007); besides, a ten-level scale was defined to assess the energy efficiency of super-market facilities (Chung et al., 2006). In the Netherlands, the EPA-ED was established to measure the energy efficiency of existing housing and establish national energy consumption benchmarks (Poel et al., 2007). In Sweden, energy consumption benchmarks for two different classes of hotel chains were developed respectively (Bohdanowicz and Martinac, 2007). In Singapore, a three-level energy efficiency scale was established and criteria defined for office buildings (Haji-Sapar). In summary, these energy efficiency scales produced an 'efficiency score' to indicate the energy performance at the 'building' level; yet they fail to inform a 'department', that often occupies only a certain floor of a building, much about the energy efficiency of its facility.

3 ESTABLISHING THE DEA ENERGY MANAGEMENT SYSTEM (DEMS)

3.1 Data envelopment analysis (DEA)

Data envelopment analysis (DEA) is a method developed to empirically measure the relative productive efficiencies of multiple 'decision making units' (DMU), such as organizations, firms or institutions, when the production process presents a structure of multiple inputs and outputs (Charnes et al., 1978). DEA measures the efficiency of a DMU by evaluating its input level relative to its output level, and comparing them against those of other DMUs. Conceptually, a DMU is considered as 'efficient' if it can produce more outputs with less inputs. A

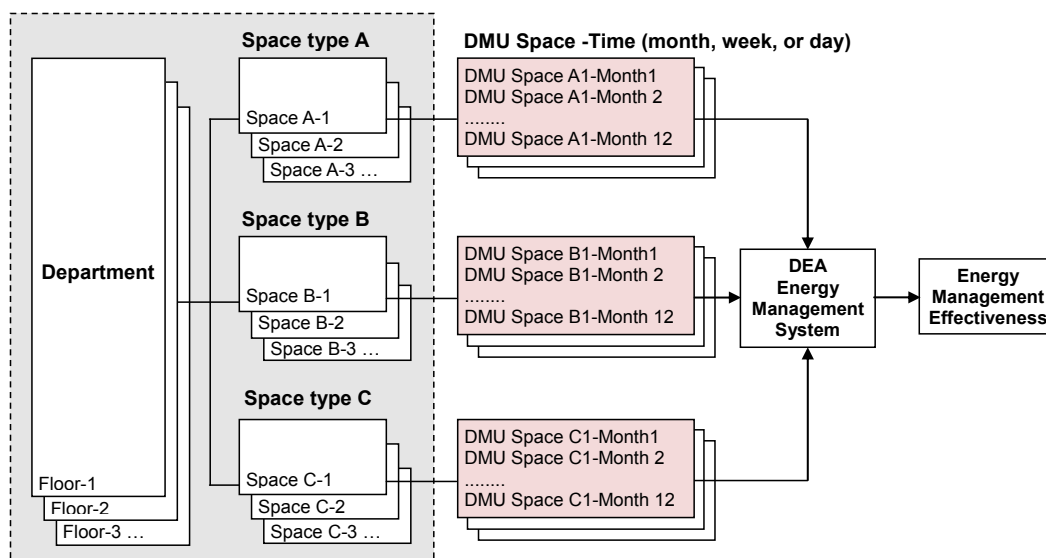
numerical efficiency score is given to each DMU, defining its relative efficiency. DEA identifies the most efficient DMUs as the benchmarks which form a 'frontier' against which the relative performance of all other DMUs can be compared. Those DMUs on the frontier are the most efficient ones and thus are given with the highest efficiency scores 100%, and all other DMUs are considered less efficient and are given with lower efficiency scores. A DMU can be made efficient either by reducing the input levels and getting the same output (input orientation) or by increasing the output level with the same input level (output orientation). In addition to providing efficiency scores, DEA can inform the less efficient DMUs of their potential benchmarks and efficiency improvement targets.

DEA has been applied to assessing the performance of organizations such as banks, hospitals and corporations. Besides, some researchers have used DEA for 'project selection' purpose (Sohn & Moon, 2004; Cook & Green, 2000; Sowlati et al., 2005). The main advantage to this method is its ability to accommodate a multiplicity of inputs and outputs. It is also useful because it takes into consideration returns to scale in calculating efficiency, allowing for the concept of increasing or decreasing efficiency based on size and output levels. A drawback of this technique is that model specification and inclusion/ exclusion of variables can affect the results (Berg, 2010). This study argues that DEA can be potentially applied to assessing the energy management effectiveness of various space types within individual departments.

3.2 The 'space-time' DMU definition

This study considers each 'space' in a given period of 'time' (a given month, week, or day) as a DMU and assess the 'energy management effectiveness' of all DMUs (Figure 1). A DMU is defined as 'a space in a month' in this study. The monthly input and output of a space (type) will be used to assess its energy management effectiveness; and each space in different months are considered as different DMUs. The 'space-time' DMU definition allows us to assess and compare the energy management effectiveness among different space types or that of a particular space over time. In other words, this approach allows us to identify 'the best practice or worst case' among different space (types) or those of a particular space (type) over time.

Figure 1: Each 'space' in a given period of 'time' is regarded as a DMU whose energy management effectiveness is further assessed by the DEMS



3.3 Multiple regression analysis to derive the predicted EUIs of all DMUs

The actual energy consumption of each space is an interacting result of three groups of factors, i.e., the 'existing environment' factors, the 'occupancy' factors and the 'management' factors. For each space (type), since its 'existing environment' conditions most likely remain unchanged over time, and its unique 'occupancy' use patterns are rather stable over time, their effects on energy consumptions can be considered predictable. If the data of the 'existing environment' and 'occupancy' factors (independent variables) of all DMUs in a department can be collected and multiple regression analysis performed on their actual energy consumptions (dependent variable), a regression model can be identified and used to predict the energy consumption of each DMU. For each DMU, the difference between its 'actual energy consumption' and 'predicted energy consumption' can be regarded as the effect of those 'management' factors. If the 'actual energy consumption' of a DMU is larger than its 'predicted energy consumption', it could be due to poor 'energy management effectiveness or conduct'; and vice versa. The 'energy management effectiveness' of all DMUs can then be further assessed by the data envelopment analysis.

In this study, 'monthly actual EUI' ($\text{Wh/m}^2\text{-month}$) is defined as the dependent variable of the regression model to be analyzed. On the other hand, the independent variables include six 'existing environment' factors such as monthly highest temperature ($^{\circ}\text{C}$), monthly highest relative humidity (%), room area (m^2), light fixture density (w/m^2), equipment density (w/m^2), and HVAC density (w/m^2); as well as two 'occupancy' factors such as occupant density ($\text{person}/100\text{m}^2$) and space use intensity (%).

3.4 The DEMS energy efficiency assessment procedure: Predicted EUIs vs. actual EUIs

The DEMS assesses the energy management effectiveness of all DMUs by analyzing their input levels relative to their output levels. The data envelopment analysis is conducted to produce the overall efficiency, scale efficiency, and pure technical efficiency scores for all DMUs to indicate their energy efficiencies from different perspectives. The DEMS procedure is as follows:

1. Defining the DEA model: Firstly, this study designates the 'predicted EUIs' of all DMUs as the 'output', and the 'actual EUI' as the 'input' of the DEMS. Then, the optimization mode and scaling mode need to be specified to generate various efficiency scores from the DEA.
2. Generating efficiency scores: Three types of efficiency scores are produced for all DMUs to indicate their energy efficiencies:
 - Overall efficiency: The 'overall efficiency' score of a DMU indicates its overall energy efficiency relative to the reference line derived from the best DMUs (with minimal inputs). The 'overall efficiency' scores reflect the effects of three groups of factors, i.e., the 'existing environment', 'occupancy' and 'management' factors.
 - Pure technical efficiency: The 'pure technical efficiency' score of a DMU indicates its energy efficiency relative to the frontier line formed by the benchmark DMUs. Those DMUs on the frontier are given with the highest 'pure technical efficiency' score 100%. The 'pure technical efficiency' scores indicate the energy management effectiveness of all DMUs and reflect the effects of the 'management' factors on energy efficiency.
 - Scale efficiency: The 'scale efficiency' scores of all DMUs can be calculated by dividing the 'overall efficiency' scores by the 'pure technical efficiency' scores. The score of a DMU can be interpreted as the best 'overall efficiency' score it can achieve given its output level (i.e., the efficiency target it should try to improve and achieve). The scores re-

flect the influences of the 'existing environment' and 'occupancy' factors on energy efficiency.

3. Score interpretation and assessment: With the above three types of efficiency scores, the DEMS allows individual departments to know the energy efficiencies of all spaces within their facilities from different perspectives, and further identify appropriate energy saving targets. In addition, the DEMS will assist individual departments in analyzing and comparing the energy management effectiveness among different 'space types' to understand the differences and the effects of various 'management' factors on energy efficiencies among different space types. Finally, the DEMS is able to analyze and compare the energy management effectiveness of a certain type of space over time to understand the pattern or trend of its energy efficiency over time and to identify critical 'management' factors that have great effects on its energy efficiencies over time.

4 AN EMPIRICAL STUDY

This study uses the Department of Architecture (DA) of a national university (NTUST) in Taiwan as a case to demonstrate how the DEMS can assist individual departments within universities in assessing the energy management effectiveness of their spaces.

4.1 The subject: The Department of Architecture, NTUST

There are about 350 occupants in the Department of Architecture of NTUST (including full time faculty members, research assistants, full time administrative staff, 200 under-graduate students, and 120 graduate students). The department occupies the 7th, 8th and 9th floor of the *Research Building* on campus. There are a total of 66 spaces in the DA of NTUST with a total floor area of 3,386 m². These spaces can be classified into five major types according to their 'functional uses': administrative office, faculty office, research lab (for graduate students), design studio (for undergraduate students), classroom (excluding spaces such as workshop, lobby, corridor, elevator, toilet and staircase).

NTUST is located in Taipei City with a humid subtropical climate. The average temperature in summer is 29.4 °C and in winter 11 °C. Summers are hot (133 days in a year with maximum temperature exceeding 30 °C) and humid (mean relative humidity 74.0~81.1%), and accompanied by occasional rainstorms and typhoons. Winters are short and mild. Taipei's average annual sunshine is 1,408 hours (67% of the time is cloudy), and average annual precipitation is 2,325 mm (46% of the days rain).

4.2 Intelligent energy monitoring system

An intelligent energy monitoring system was installed in the DA in August 2011 to record the electricity consumption data of lighting, equipment, and HVAC on each of the three floors. In addition, the system also records the electricity consumptions in five typical spaces, each representing one of the five major space types: Cls809 (classroom), Adm810 (administrative office), Fac905 (faculty office), Lab906 (research lab), and Std909 (design studio). The logged data can be tabulated into hourly, daily, or monthly data tables for reference. The monthly actual EUIs of the five spaces and those of department average in year 2012 will be used as the data of a dependent variable 'actual EUI' for further analysis and are summarized in Table 1.

Table 1: The monthly actual EUIs of the five space types and the department average in the DA, NTUST

	2012 Jan	2012 Feb	2012 Mar	2012 Apr	2012 May	2012 Jun	2012 Jul	2012 Aug	2012 Sept	2012 Oct	2012 Nov	2012 Dec	Total kWh/m ²
Cls809 (8 th fl) Classroom	4.8	4.0	6.5	6.7	13.4	9.3	6.9	5.5	11.3	9.3	8.6	5.2	91.5
Adm810 (8 th fl) Admin. office	4.2	4.2	5.6	5.5	7.3	7.5	9.6	7.4	8.4	6.6	6.8	5.3	78.3
Fac905 (9 th fl) Faculty office	2.8	3.6	4.0	4.4	5.3	6.9	8.3	5.9	6.5	4.3	3.8	3.9	59.5
Lab906 (9 th fl) Research lab	4.2	4.2	4.7	6.2	8.4	10.1	14.6	9.7	10.7	12.4	13.1	7.4	105.6
Std909 (9 th fl) Design studio	2.3	2.2	4.0	5.3	7.4	9.6	10.9	2.5	5.4	10.0	7.8	5.9	73.4
Department average	4.2	3.6	6.2	8.1	10.4	10.2	11.2	7.7	8.1	9.1	8.5	6.3	93.7

4.3 Assessing the energy management effectiveness of the DA, NTUST

The collected data aforementioned are used as the input data of the DEMS for assessing the energy management effectiveness of the DA, NTUST. The following steps are taken:

1. DMU definition: Each space in a particular month is considered as a DMU. As a result, there are a total of 60 DMUs (= 5 spaces*12 months) for a full year in this study.
2. Data collection: Data of six 'existing environment' variables and two 'occupancy' variables are collected from five spaces in each month. The descriptive statistics of eight independent variables and one dependent variable of summarized in Table 2.

Table 2: The descriptive statistics of eight independent variables and one dependent variable

	Indep. variables Existing environment factors						Indep. variables Occupancy factors		Dependent variable
	X1 Outdoor highest temp (°C)	X2 Out- door highest humidity (%)	X3 Room Area (m ²)	Lighting density (watt/m ²)	Outlet Density (watt/m ²)	X4 HVAC Density (watt/m ²)	X5 Occupant density (per/m ²)	X6 Space use intensity (%)	Y Monthly EUI (Wh/m ²)
Minimum	22.8	85.3	20.0	12.9	6.6	25.0	2.3	25.0	2194.0
Maximum	36.1	87.7	264.0	19.5	48.7	541.9	14.6	100.0	14558.5
Average	31.3	86.3	141.4	15.5	23.8	155.7	8.1	84.6	6805.0
Standard deviation	4.0	0.7	86.9	2.4	16.3	196.8	4.3	20.1	2887.2
Sample number (N)	60	60	60	60	60	60	60	60	60

3. Multicollinearity check: Correlation coefficients among the six 'existing environment', two 'occupancy' independent variables ('management' factors NOT included) and one dependent variable 'month actual EUI' are first calculated to check whether there are multicollinearities among the eight independent variables. As a result, high correlation coefficients ($|r| > 0.5$) are observed between 'lighting density'/'outlet density' and other variables such as 'room area', 'HVAC density' and 'occupant density' ($0.52 < |r| < 0.82$) and therefore both are excluded from the multiple regression analysis for 'multicollinearity' concern.
4. Multiple regression analysis: Multiple regression analysis is performed on the remaining four 'existing environment' independent variables (X1 outdoor highest temperature; X2 outdoor highest humidity; X3 room area; X4 HVAC density), two 'occupancy' independent variables (X5 occupant density; X6 space use intensity; 'management' factors

NOT included) and a dependent variable 'monthly actual EUI' (Y; wh/m²). The statistical analysis indicates that this regression model has a R² of 60.4% and the regression equation (1) is:

$$Y = 362.4^{***} \times X1 + 388.6^{*} \times X2 + 5.7^{+} \times X3 + 4.1^{**} \times X4 + 61.6^{***} \times X5 + 249.5^{***} \times X6 + 20053.3 \quad (\text{where P-value } ^{+}<0.10, ^{*}<0.05, ^{**}<0.01, ^{***}<0.001}) \quad (1)$$

5. Calculate the 'predicted EUIs' of five types of spaces: The derived regression equation is used to calculate the 'monthly predicted EUI' (Wh/m²-month) of all DMUs by feeding the values of six independent variables into the equation (column 'Predicted EUI' in Table 3).
6. Conduct data envelopment analysis: The Frontier Analyst™ software is used to conduct data envelopment analysis on the actual EUIs (input) and predicted EUIs (output) of all DMUs. The 'overall efficiency' scores of all DMUs are obtained when the minimal input and the CCR models (constant returns to scale) are specified for DEA analysis. The 'pure technical efficiency' scores of all DMUs are obtained when the maximal output and BCC models (variable returns to scale) are specified. The 'scale efficiency' scores of all DMUs can be calculated by dividing the 'overall efficiency' scores by their 'pure technical efficiency' scores (Table 3). Figure 2 shows the scattered plot of 'predicted EUIs' and 'actual EUIs' of all DMUs, the frontier line connecting the DMUs with the highest pure technical efficiency scores (P1~P5) and the regression line (EF).
7. Inspect the overall, scale and pure technical efficiency scores of all DMUs:
 - 'Overall efficiency' scores reveal the relative efficiency of all DMUs as compared against the benchmark efficiency derived from the best case DMU Cls809-3 (Classroom809 in March), whose actual EUI is relatively low (3985.1 wh/m²) and is reduced tremendously from its predicted EUI (8253.9 wh/m²) possibly due to certain management effort. The average overall efficiency score of all DMUs is only 51.3%, and the scores of the majority of DMUs lie between 30~70%, as indicated by Table 3 and Figure 3.

Table 3: Actual EUIs, predicted EUIs, and three types of efficiency scores for all DMUs (space-month)

DMU (space-month)	Actual EUI (wh/m ² -month)	Predicted EUI (wh/m ² -month)	Overall efficiency (%)	Scale efficiency (%)	Pure tech. efficiency (%)
Cls809-1	4780.3	5828.0	58.9%	89.9%	65.5%
Cls809-2	3950.0	4456.7	54.5%	99.8%	54.6%
Cls809-3	6480.7	8895.8	66.3%	76.6%	86.6%
.....
Cls809-7 (P4)	6946.3	10648.2	74.0%	74.0%	100.0%
Cls809-8	5450.3	5637.3	49.9%	83.6%	59.7%
.....
Cls809-12	5224.0	4877.9	45.1%	85.6%	52.7%
Average	7623.1 (4)	7603.8 (4)	50.8% (2)	70.9% (4)	73.2% (3)
Adm810-1	4211.1	3043.5	34.9%	96.7%	36.1%
Adm810-2	4150.9	3827.7	44.5%	97.6%	45.6%
Adm810-3	5564.0	6111.4	53.0%	82.7%	64.1%
.....
Adm810-7	9636.7	10019.1	50.2%	55.6%	90.3%
Adm810-8	7430.7	6549.2	42.6%	69.8%	61.0%
.....
Adm810-12	5287.3	3634.4	33.2%	84.9%	39.1%
Average	6523.3 (3)	6257.1 (2)	45.9% (5)	77.0% (2)	61.4% (4)
Fac905-1	2820.0	2403.4	41.1%	86.0%	47.8%
Fac905-2	3566.5	3187.6	43.2%	96.2%	44.9%
Fac905-3	4002.5	3930.3	47.4%	99.8%	47.5%
.....
Fac905-7	8347.5	7838.1	45.3%	62.9%	72.0%
Fac905-8	5892.5	7450.0	61.0%	80.2%	76.1%
.....

Fac905-12	3855.0	2994.3	37.5%	98.9%	37.9%
Average	4961.7 (1)	5103.4 (1)	49.4% (3)	87.4% (1)	57.5% (5)
Lab905-1	4244.5	6467.7	73.6%	96.3%	76.4%
Lab905-2	4229.3	5710.9	65.2%	96.4%	67.6%
Lab905-3	4699.8	6453.6	66.3%	90.7%	73.1%
.....
Lab905-7 (P5)	14558.5	11902.3	39.5%	39.5%	100.0%
Lab905-8	9681.2	6891.4	34.4%	55.4%	62.1%
.....
Lab905-12	7355.9	5517.6	36.2%	70.3%	51.5%
Average	8803.3 (5)	7883.5 (5)	48.1% (4)	65.2% (5)	74.8% (2)
Std909-1 (P2)	2321.0	3645.1	75.8%	75.8%	100.0%
Std909-2 (P1)	2194.0	2621.5	57.7%	57.7%	100.0%
Std909-3 (P3)	3985.1	8253.9	100.0%	100.0%	100.0%
.....
Std909-7	10893.1	10353.8	45.9%	50.1%	91.6%
Std909-8	2514.8	3802.0	73.0%	80.3%	90.9%
.....
Std909-12	5926.2	5776.9	47.1%	80.1%	58.8%
Average	6113.7 (2)	7177.2 (3)	62.2% (1)	71.6% (3)	86.6% (1)

Figure 2: The scattered plot of the 'predicted EUI' and 'actual EUI' of all DMUs, the frontier line (P1-P2-P3-P4-P5) and the regression line (EF).

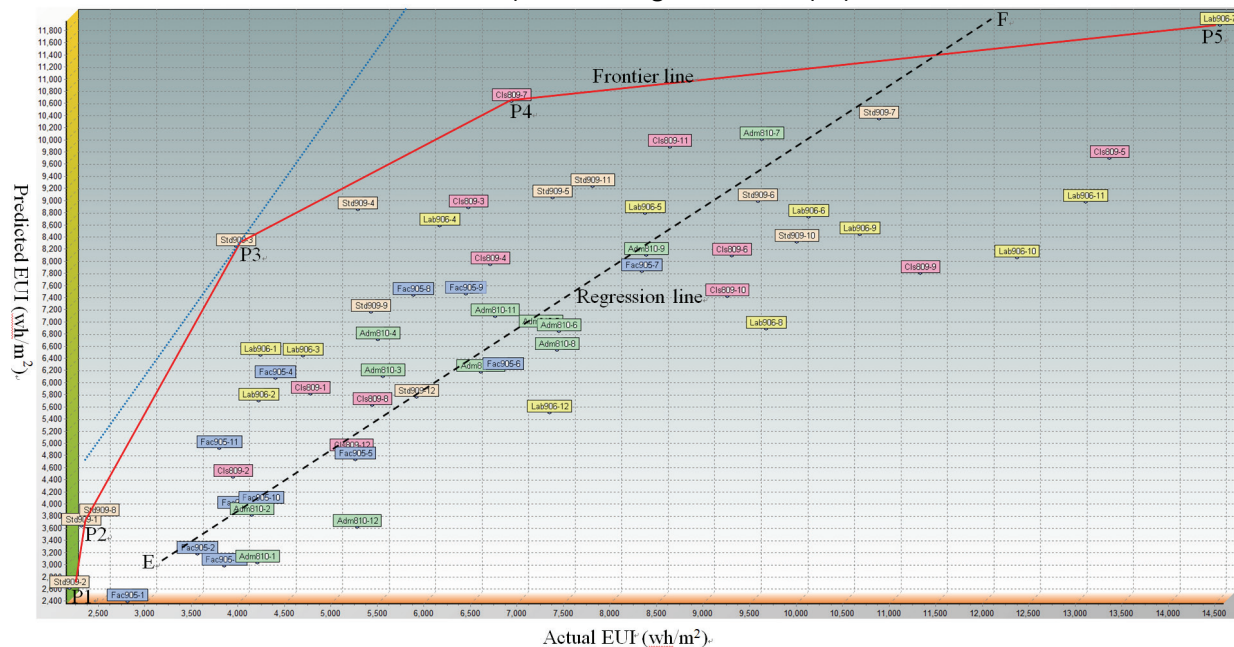
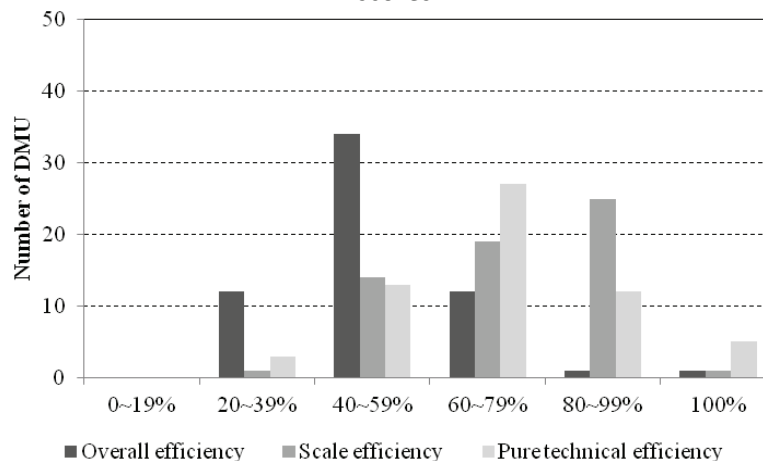


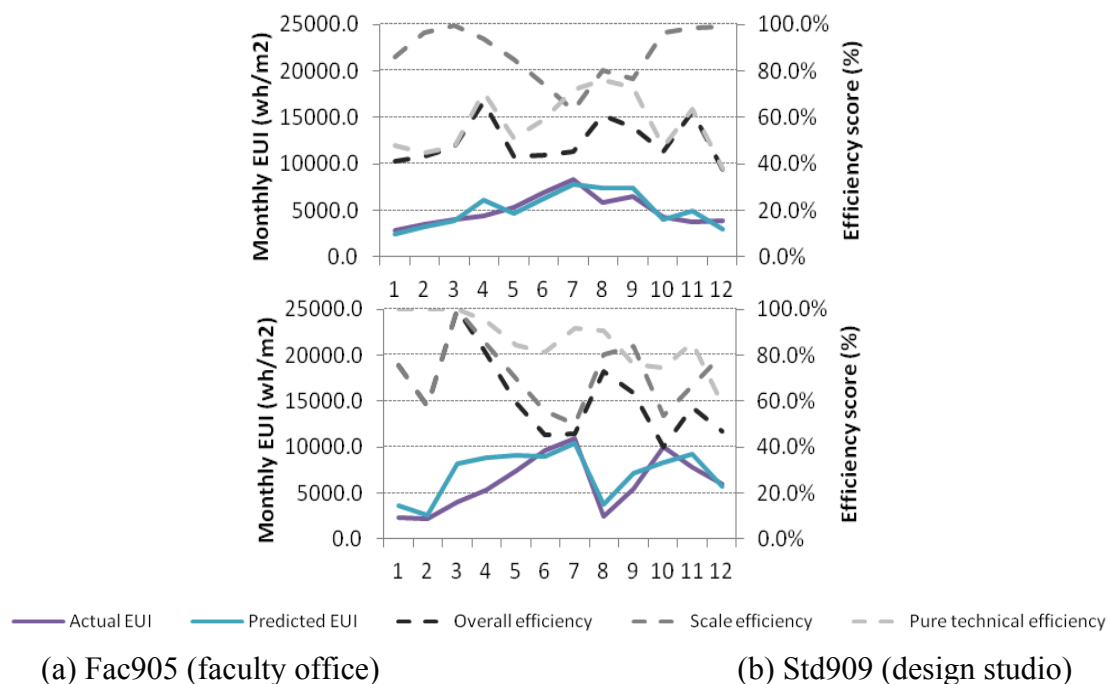
Figure 3: The histograms of the overall efficiency, scale efficiency and pure technical efficiency scores



- 'Scale efficiency' scores reveal the benchmark 'overall efficiency' those DMUs can aim to achieve at a certain output level (predicted EUI). The average scale efficiency score of all DMUs is as high as 74.4%, and the scores of the majority of DMUs lie between 50~90%, as indicated by Table 3 and Figure 3.
 - 'Pure technical efficiency' scores reveal the relative efficiency of certain DMUs as compared against the efficiency established from the benchmark cases (Std909-2, Std909-1, Std909-3, Cls809-7, Lab905-7) who have the highest scores of 100% and form the frontier line P1-P2-P3-P4-P5 in Figure 2. These five DMUs have high management effectiveness because their 'actual EUIs' are reduced to the levels much lower than their 'predicted EUIs'. Whereas those DMUs far away from the frontier line, such as Adm810-12, Fac905-12 and RBAdm810-1, have scores as low as 39.1%, 37.9% and 36.1% (Table 3), meaning that these three spaces in particular months are the least effective in terms of energy management, resulting in their 'actual EUIs' much higher than the 'predicted EUIs'. The average overall efficiency score of all DMUs is 70.3%, and the scores of the majority of DMUs lie between 50~90%. It is suggested that those less efficient DMUs below the regression line in Figure 2 reduce their 'actual EUIs' to the 'predicted EUIs' levels, or even better, to the levels of their benchmarks on the frontier line (move horizontally towards the regression line or frontier line).
8. Assess energy management effectiveness among different 'space types': The 'actual EUIs', a widely used energy efficiency indicator, show that on average Fac905 (faculty office) is the most energy efficient space (lowest monthly average EUI of 4961.7 wh/m²); Lab905 (research lab) is the least energy efficient space (highest monthly average EUI of 8803.3 wh/m²); and with a rank order of Fac905 > Std909 > Adm810 > Cls809 > Lab905 among five space types. However, the 'pure technical efficiency' scores reveal different results from the 'management' perspective and show that Std909 (design studio) is the most effective space (highest average score of 86.6%); on the contrary, Fac905 (faculty office) is the least effective space (lowest average score of 57.5%); and with a rank order of Std909 (86.6%) > Lab905 (74.8%) > Cls809 (73.2%) > Adm810 (61.4%) > Fac905 (57.5%). The result is somewhat counter-intuitive because the occupancy patterns of the Fac905 (faculty office) and Adm810 (administrative office) are considered relatively stable and predictable, and therefore both rooms are normally assumed more energy efficient. On the other hand, the occupancy patterns of Cls809, Lab906, and Std909 used by students are variable and less predictable, and therefore they are often regarded as less energy efficient.
- Careful inspection on the differences between the actual EUIs and predicted EUIs of all types of space reveal that Adm810 and Fac905 are least effective from 'management' perspective because eight out of their twelve actual EUIs are larger than the predicted EUIs in both cases (even though the differences between the actual and predicted EUIs are considered small as compared to those of other three spaces); but only four or five out of the twelve actual EUIs are larger than the predicted EUI in the cases of Std909 and Cls809.
 - It is further conjectured that the inclusion of winter and summer months could be the cause. Administrative and faculty offices are often used during winter and summer breaks; whereas classrooms, research labs, and design studios are often not used during the breaks, so that there are fewer DMUs whose actual EUIs are larger than predicted EUIs, and thus resulting in higher management effectiveness.

- Further investigations are required to figure out what results in larger differences between the actual and predicted EUIs of Cls809, Lab906 and Std909 occupied by students.
9. Assess energy efficiency of each space type 'over time': Faculty office Fac905 and design studio Std909 are used to illustrate the results (Figure 4).
- The actual and predicted EUIs of Fac905 are considered low (range from 2500 to 8500 wh/m²), and the discrepancies in both types of EUIs are small. In Figure 4a, the margins of the differences between the predicted EUIs and actual EUIs are much more observable in April, August, September and November (predicted>actual, more effective) than in other months (actual>predicted, less effective). Three types of efficiency scores reveal similar findings. The 'overall efficiency' and 'pure technical efficiency' scores, ranging 40~60% and 40~80%, are considered low relatively, because the Fac905 DMUs are compared against the reference line derived from the best case Std909-3 to produce their 'overall efficiency' scores and against the frontier line formed by the benchmark cases (P1-P2-P3-P4-P5) to produce their 'pure technical efficiency' scores. Nevertheless, the overall and pure technical efficiency scores peak in April, August, September and November as well. It is suggested that Fac905 reduce its energy consumptions from the actual EUIs to the predicted EUIs in certain months, or even better, to the benchmark input levels established by the frontier line.
 - Std909 is considered the most efficient case as compared to other four spaces, because its energy consumptions are relatively low in January, February and March, August and September; and its actual EUIs are much lower than the predicted EUIs in March through May, resulting high overall and pure technical efficiency scores in these months (Figure 4b). It is suggested Std909 reduce its actual EUIs in June, July and October to further improve its energy efficiency and management effectiveness.

Figure 4: Energy consumptions and efficiency scores of Fac905 & Std909 over 12 months in 2012



4.4 Discussions

Essentially, the DEMS is developed to perform data envelopment analysis on the predicted EUIs and actual EUIs of various types of space to identify benchmark cases or DMUs (space in month) against which to produce three types of energy efficiency scores for individual spaces over time to indicate their energy efficiency in a relative term.

The empirical results in this study show that the DEMS has the potentials to assist individual departments within universities in their energy management tasks at two levels. Firstly, it allows facility managers to assess and compare the energy efficiency scores 'among different spaces'; to further investigate why a certain space is particularly effective or ineffective; and to identify benchmark 'spaces' for ineffective spaces. Secondly, it allows facility managers to further review the energy efficiency of a space 'over time'; to identify the ineffective months when the actual EUIs of a space are higher than the predicted EUIs and possible causes; and to recognize the benchmark cases or DMUs (space in month) and pursue actions for energy improvement.

Nevertheless, it is also important to recognize the assumptions and limitations of the DEMS in order to further improve the DEMS for practical use. Firstly, the accuracy of the energy efficiency scores depends greatly on the accuracy of the predicted EUIs of spaces and therefore it is critical to identify a better regression model with higher predictability (R^2). Secondly, the relatively low actual EUIs of certain student spaces during winter and summer breaks may greatly affect the resulting energy efficiency scores and may not truly reflect the overall picture of relative energy effectiveness among different spaces. It is important thus to exclude data during winter and summer breaks and to re-examine the resulting energy efficiency scores.

5 CONCLUSION

This research explores the 'space type' and 'internal benchmark' research concepts, and the 'data envelopment analysis' method to establish the 'DEA Energy Management System (DEMS)' in order to assist individual departments within universities in assessing the energy efficiencies of their facilities from the 'management' perspective. The DEMS is further implemented in the Department of Architecture of NTUST in Taiwan to show its analytical procedures and results, and to discuss its potential and limitations from the energy management perspective.

Overall speaking, from the empirical case study of DEMS application, this study finds it able to reveal the energy efficiencies and energy management effectiveness of all DMUs, and to identify energy saving target for all DMUs. Nevertheless, several future research directions are outlined:

1. Increased sample or DMU size to improve the R^2 of the regression model to at least 80%.
2. Exclude the months of winter and summer breaks from the data envelopment analysis.
3. Explore studies including only the DMUs in the same months (not in a year) for analysis.

REFERENCES

- Berg, S. (2010). *Water Utility Benchmarking: Measurement, Methodology, and Performance Incentives*. International Water Association.
- Bohdanowicz, P. and Martinac, I. (2007) Determinants and benchmarking of resource consumption in hotels – Case study of Hilton International and Scandic in Europe. *Energy and Buildings* 39 (1), 82-95.
- Charnes, A., Cooper, W.W. and Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units, *European Journal of Operational Research*, 2(6), 429-444.
- Chauhan, N.S., Mohapatra, P.K.J. and Pandey, K.P. (2006). Improving energy productivity in paddy production through benchmarking - An application of data envelopment analysis. *Energy Conversion and Management*, 47, 1063-1085.
- Chung, W., Hui, T.V. and Lam, Y.M. (2006). Benchmarking the energy efficiency of commercial buildings. *Applied Energy*, 83 (1), 1-14.
- Cook, W.D. and Green, R. H. (2000). Project prioritization: a resource-constrained data envelopment analysis approach, *Socio-Economic Planning Sciences*, 34(2), 85-99.
- Filippin, C. (2000). Benchmarking the energy efficiency and greenhouse gases emissions of school buildings in central Argentina. *Building and Environment*, 35, 3206-3217.
- Hatamipour, M.S., Mahiyar, H. and Taheri, M. (2007). Evaluation of existing cooling systems for reducing cooling power consumption. *Energy and Buildings* 39, 105–112.
- Haji-Sapar, M. and Lee, S.E. (2005). Establishment of energy management tools for facilities managers in the tropical region. *Facilities*, 23, (9/10), 416-425.
- Lee, W.L., Yik, F.W.H. and Burnett, J. (2007). Assessing energy performance in the latest versions of Hong Kong Building Environmental Assessment Method. *Energy and Buildings*, 39 (3), 343-354.
- Önüt, S. and Soner, S. (2006). Energy efficiency assessment for the Antalya Region hotels in Turkey. *Energy and Buildings*, 38 (8). 964-971.
- Poel, B., Cruchten, G.V. and Balaras, C.A. (2007). Energy performance assessment of existing dwellings. *Energy and Buildings*, 39 (4), 393–403.
- Sohn, S.Y. and Moon, T.H. (2004). Decision Tree based on data envelopment analysis for effective technology commercialization, *Expert Systems with Application*, 26(2), 279-284.
- Sowlati, T., Paradi, J.C. and Suld, C. (2005). Information systems project prioritization using data envelopment analysis, *Mathematical and computer modeling*, 41(11-12), 1279-1298.
- Tu, K.J. and Lin, C.H. (2012). Benchmarking Energy Efficiency by ‘Space Type’: An energy management tool for individual departments within universities. *Journal of Asian Architecture and Building Engineering*, 11 (2), 299-306.

CHAPTER 7

USABILITY AND USER EXPERIENCES

7.1

User Experience of Creative Class District: Studying Punavuori Neighborhood in Helsinki

Sari Tähtinen, Inka Kojo and Suvi Nenonen

7.2

The Users' Relocation Process: A University Faculty's Staff Experiences

Christopher Heywood, Peggie Rothe and Anna-Liisa Sarasoja

7.3

Usability Briefing – A Process Model for Complex Buildings

Aneta Fronczek-Munter

7.4

People Flow and Experienced Safety – Use-Centric Method to Improve the Product

Hannu Nousu, Terhi Väistö, Suvi Nenonen and Astrid Mangs

7.1

USER EXPERIENCE OF CREATIVE CLASS DISTRICT: STUDYING THE PUNAVUORI NEIGHBORHOOD IN HELSINKI

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ABSTRACT

Purpose: This research presents empirical testing of an experience-based usability framework to study an urban area. The framework is applied to the Punavuori neighbourhood in Helsinki, Finland to understand the issues that make this neighbourhood attractive to its users.

Background: The experience-based usability framework for an urban area study is the 6T-model of experience of place, which was developed by combining service and experience design tools and methods to assess the user's experience.

Approach: The framework is tested by analysing data gathered from documents, a walkthrough of the neighbourhood and interviews.

Results: This paper interprets users' experiences of the Punavuori area using the 6T-model to capture new perspectives on user-centric urban design and the management of places. The identified connections can be a starting point for investigations into users' experiences as a part of the usability of an urban area.

Practical Implications: The results can be used in other experience-based research for the enhance the desirability of new or existing areas to attract new inhabitants and businesses. The results can be applied by urban planners as well as place managers.

Research limitations: The results represent a beginning study into the usability and user experiences of urban areas. The preliminary testing of the experience framework is used as a framework for the analysis of the secondary data. The user data have not been gathered in the broadest sense.

Originality/value: Applying users' experiences to identify points of connection is valuable and unique in the solution-based analysis of the urban context.

Keywords: Experience, Urban planning, Spaces, Places, Place management

1 INTRODUCTION

Developing creative industry is a powerful means to transform urban areas and improve the economic foundation and competitiveness of a city. Punavuori, an area near the city centre with a somewhat bad reputation, has turned into a flourishing part of Helsinki. The area can be investigated through the so-called “creative class” idea as described by Richard Florida (2002). From this point of view, development appears to be a positive phenomenon. The other approach in urban studies is the so-called gentrification discussion, which looks at development from the perspective of the inhabitants that can no longer afford to live in the now attractive area due to the rising prices. Lees, Slater and Wylie (2008) describe gentrification as the transformation of a working-class or vacant area in the central part of a city into a middle-class residential or commercial area. Gentrification is negative and takes an oppositional stance to Florida’s views. With the experience-based usability framework, we attempt to bypass the oppositional logic of these two approaches and, instead, identify the connections linking the different user experiences of the urban area.

Increased involvement of the creative industry and urban innovation go hand-in-hand: innovative urban areas attract creative people, and creative industries help spur on new urban innovations. The aim of urban innovation is to regenerate the shrinking traditional industry and improve city life through the implementation of new and smarter ways to utilise physical space, engage local people, stimulate the economy, protect the environment and advance cultural activities (Xiaowu, 2006). The role of spatial structure and urban narrative in an individual’s experience of a place has been previously investigated by Perdikiogianni (2007). She claims that spatial structure describes the actual space that an individual navigates and occupies during his or her daily activities. Alternatively, the term urban narrative describes the factors in urban history and social culture that create an imagined space, evolve through historical time and are navigated through a city’s cultural mythology.

In investigating an individual’s use and response to a place, it is important to see places as subjective, imagined and emotional phenomena as well as objective and real entities. A creative worker’s subjective, personal or emotional response to a place will affect how they use its attributes for aesthetic inspiration, and that response will be moulded by individual identities, perceptions and beliefs. Collective imaginations and emotions emerging from different groups or subcultures within the local population may mould the individual’s response (Bennett, 2000).

This research presents the empirical testing of an experience-based usability framework to an urban area study. The framework is applied to the Punavuori neighbourhood in Helsinki, Finland to understand the issues that make the area attractive to its users. Punavuori is located within walking distance of the Helsinki town centre and favours inhabitants and businesses from the creative industries, including artist studios, design boutiques and trendy bars and restaurants, among others.

How can an experience-based usability framework, which was developed by combining service and experience design tools and methods to assess users’ experiences, be applied in the research of urban areas? More specifically, we seek to conceptualise users’ experiences of urban areas by analysing the different types of data with this framework.

The paper discusses conceptualisations of users' experiences and examines existing theories of socio-spatial systems. The paper then analyses empirical data obtained from document analysis, a walkthrough of the neighbourhood and interviews before suggesting how the experience-based approach could be extended to recognise links between subjective and objective assessments of urban areas.

2 EXPERIENCE-BASED USABILITY FRAMEWORK FOR AN URBAN AREA

2.1 Usability and urban area

In studies of the usability of built environments, usability is dependent on the context and users' perceptions and experiences. Small scale usability evaluations are based on users' experiences and assessments on how well the buildings perform regarding different parameters. A building's performance can never be understood in isolation from an organisational and technical perspective, as those aspects interact and influence each other (Alexander et al., 2013). Shields (1991) uses the term social spatialisation to designate the on-going spatial construction of space at the level of social imagery (collective mythologies, presuppositions) as well as the interventions in landscapes (for example, built environments). Therefore, a dual relationship exists between people and space; people act according to social factors (gender, glass, race, age, status) within a given space (Gottdiener & Hutchison, 2011).

The challenges in the research of usability of built environments appear similar at different scales of urban environments. While research into the usability of the workplace (Alexander et al., 2013) has challenged conventional approaches to briefing and post-occupancy evaluations in connection with a variety of building segments, according to Perdikogianni (2007), the current scientific challenge in urban development is to develop methods that combine the analysis of urban structure, design and morphology with the broad, qualitative investigation of individuals' and the community's perceptions, attitudes and aspirations.

There is a lack of methods that address the physical and attitudinal aspects of urban areas as spatial, social and economic phenomenon together. The usability of a built environment is "a cultural phenomenon that can only be improved through a better understanding of user experience, considered as situated action in a specific context" (Alexander, 2008). Alexander (2010) argues for greater emphasis on user experience and suggests reconsidering the original triumvirate of efficiency, effectiveness and satisfaction to substitute experience for satisfaction. According to Csikszentmihalyi (1990), the experiences of the past are described in terms of satisfaction, the future with hope and the present situation with presence and mindfulness. Recent work on service design and space management draws upon work about experience design (Shedroff, 2009). The development of service design and especially experience design has provided new tools and methods to assess the user's experience of spaces and places. Nenonen & Kojo (2013) developed a six dimensional model of experience of place that has proved to be suitable in the workplace development context, and this model is tested in this study in the context of urban areas.

By definition, a socio-spatial system involves interaction between people and their built environment. So far, there is a lack of ability to combine subjective, often qualitatively described, user experiences with objectively defined standards of built environments. To understand the platform where interaction happens, one must capture both the tangible and intangible layers. Instead of focusing on spatial characteristics and objective, measureable and managerially

controllable factors, one should focus on subjective, immeasurable and often managerially uncontrollable social, symbolic and restorative stimuli, which all influence social interaction. Social, symbolic and restorative stimuli are often the drivers of profound person–place attachments. (Rosenbaum & Massiah, 2011.) As a human geographer, Tuan (1977) considers the ways in which people feel and think about a space, how they form attachments to home, neighbourhood, and nation, and how feelings about space and place are affected by the sense of time. He suggests that place is security, whereas space is freedom; we are attached to security and long for freedom. When considering the experience of place, Forlizzi and Battarbee (2004) state that user experiences need to be approached through the emotions and meanings that users attribute to them. Emotion is at the heart of any human experience and is an essential component of it (Forlizzi & Battarbee, 2004).

2.2 6T-model of experience of place

The connection among user-experience, design thinking and business anthropology has been previously used, for example, in an ethnographic account of relations among groups across Notting Hill, West London. From a psychological and anthropological stance, place is found in the dynamic contrast of the different forms of validity given by humans who carry a place and, in return, are carried by it. Such a view carries direct implications for the fields of user experiences, design planning, urban policies of space and the interaction between business anthropology and usability (Oliveira, 2011). Drake (2003) has studied the extent to which workers in the creative industries acknowledge place as a source of creative stimuli and ideas.

By bringing the experience-based usability framework to the research of urban areas, intangible experiences are categorised into six different dimensions. The dimensions are overlapping, but they provide a framework to structure a holistic, intangible experience, such as the user's journey in a specified area. The framework is called the 6T-model and is used to capture a user's experience of a place. The 6T-model is modified through adductive reasoning using Diller et al.'s (2005) classification of experience (Nenonen and Kojo 2013). During this research, the conceptually developed, model and the former abstract dimensions were replaced with six descriptive and aligned words that have a similar first letter.

The 6T-dimensions of user experience are the following:

1. **Tune** concerns the atmosphere of the place and includes elements that affect the holistic sense-experience of the place: smelling, tasting, seeing, feeling, and hearing. Additionally, different cognitive symbols (such as signs) are related to this dimension.
2. **Tempo(rality)** refers to activities happening in the rhythm and tempo of the place. This dimension is connected to the use, sense and rhythm of time in the place as well as diverse chronotypes. This dimension also includes the sense of history.
3. **Task** is about the functionality of the place and indicates how the place supports the activities that are conducted there. It also includes the ease of changing the place for different purposes or the adaptability of the place.
4. **Tie** is about the familiarity of the place and refers to the ease of use of the place, such as the effortless adaption to the place and the learnability that ties the user's cognitions to the place.
5. **Tale** refers to the narrative of the place. One can identify the constancy and coherency of the story of the place. Features such as identity, brand, and purpose of the place relate to this dimension.

6. (Tenor) **Theme** is about the meaning and significance of the place to its users. It relates to tangible and intangible values as a part of the place experience. The meaning of the place relates to the concepts of appropriation, attachment, belonging, ownership, control and privacy.

The 6T-model as a framework that includes a set of questions that can be used as a tool for analysing experiences (Table 1).

Table 1: From six dimensions to six T-expressions

Significance T-concept	Meaning and relevant questions for assessment
Tune Atmosphere	The tune indicates the first expression of the experience. <ul style="list-style-type: none"> • How do we feel in the place? • What kind of sensual and emotional experience is it? • What is the first impression based on sensual, emotional and cognitive triggers?
Tempo(rality) Frequency	Temporality indicates the state of existing within or having some relationship with time. <ul style="list-style-type: none"> • How do we experience the history/presence/future of the place? • What is the rhythm and tempo of the place?
Task Functionality	Task indicates the charge, assignment, detail, mission, engagement, occupation, undertaking, exercise, business and responsibility that are connected to the purpose of being in the place. <ul style="list-style-type: none"> • How does the place help me fulfil the task I am supposed to do? • How can I affect the place to fulfil the task I am supposed to do?
Tie Familiarity	Tie indicates the connections and links and how we use them. They are the things that link our behaviour in a place with cognitive and social maps. <ul style="list-style-type: none"> • How easy is it to connect to the place? • How much effort do I have to give for fluent connectivity?
Tale Narrative	Tale indicates the story and narrative of the place and has these synonymous expressions: anecdote, history, legend, fable, myth, parable, allegory and saga. <ul style="list-style-type: none"> • What kind of story does the area tell? • How is the story told? • How consistent is the story?
(Tenor) Theme Significance	The theme indicates the general meaning, sense, or content of a place to its users and includes the course of a person's life or habits. <ul style="list-style-type: none"> • What is the meaning of this place to me? • What effort am I willing to make in this place? • How important is the place to me?

3 RESEARCH DESIGN

The framework is applied to data from the Punavuori neighbourhood in Helsinki, Finland to understand what makes the neighbourhood attractive to its users. The 6T-model was used for retrospective analysis of secondary data (quantitative and qualitative) and applied to individual walkthroughs.

3.1 Data

The data used in this study are described in Table 2 and the following sections.

Table 2: Data used

Data	Type of data	Method
Orientation to Punavuori area		
Statistical Analysis (Alanen)	Secondary	Background data
Experience analysis of subjective walkthrough in Punavuori		
Walkthrough (video documented)	Primary	Video analysis
Experience analysis of local actors in Punavuori		
Interviews of media entrepreneurs	Secondary	Content analysis with 6T-model
Interview of the founder of the residential association, designer	Primary	Content analysis with 6T-model

3.1.1 Orientation to Punavuori area and statistical data

Punavuori is an example of a place with a dubious reputation that has changed into a trendy urban environment that is attractive to both business and living. All of these changes appeared to have taken place without any specific development or planning. Punavuori is situated in the southwestern part of the Helsinki peninsula. It has been part of the planned town area since the 1875 city plan. In the 1886 plan, the area was designated as an industrial area, and some industrial buildings were built. However, according to the 1900 city plan, the ideas of a large-scale industrial area were abandoned. With this background, the area developed as an industrial area and a residential area for the labour force. It was one of the most densely populated areas after the Second World War. Due to crime and violence, Punavuori gained a bad reputation. Since the 1990s, Punavuori has changed from a slum into a Design District. Today, it is part of the downtown Helsinki area, with a prominent presence of what Richard Florida has called the creative class.

What makes Punavuori different from many other downtown areas is that the nearby shipyard kept small industrial businesses, such as metal workshops, in the area until as late as the 1980s. These industrial activities took place in two large industrial buildings, Mestaritalo and Merikortteli. These two buildings avoided the pressure to be turned into housing, and they were able to keep their users mixed and varied. This diversity may be a factor for the change of the area. The oldest parts of Mestaritalo are from 1898, and its current form dates from 1943. Fazer was in the building until 1961, at which time it moved away in phases. Until the 1980s, metal workshops needed by the shipyard still functioned in the building. Merikortteli was built in 1934. The red brick factory was among the first in Finland to be designed for use by multiple companies. From Merikortteli's courtyard, the Finnish Cable Factory supplied the nation with telephone cables, and the light manufacturer Airam illuminated not only Finnish homes but also the scoreboard of the Helsinki Summer Olympics in 1952 (Jutikkala, et al. 1956; Rosén, R. et al. 1955; 1956; Hakkarainen and Putkonen 1996; Turpeinen et al. 1997; Schulman et al. 2000).

Alanen (2007) has studied the Punavuori area, and his statistical analysis, as shown in Tables 3 and 4, supports the notion that the area is especially attractive to designers and media entrepreneurs.

Table 3 The share of designing services in the Punavuori area in terms of turnover in 2005
(Alanen, 2007)

Designing services in Southern Helsinki (2005)	Architectural services	Advertising services	Industrial design services
Punavuori share in terms of turnover %	6.0	14.9	4.1

Table 4: The share of staff distribution in Punavuori area in 2005 (Alanen, 2007)

Staff distribution in Southern Helsinki	Constructing engineering	Architecture	Advertising	Industrial design
Punavuori share %	0.3	7.7	7.2	5.1

However, the statistics do not provide reasons why these people find the area attractive and why they wish to work and live there.

3.1.2 Data for experience-based usability evaluation

A walkthrough was conducted to collect the impressions of the area. The walkthrough was conducted and recorded on March 15, 2014 around early noon. To bring out different user experiences of the area, the study looked at two user groups that were active at the time the change took place. The first group consists of media entrepreneurs, which were interviewed by Karvala (2008). The interviews are summarised in *Maine* magazine. There is also a description of the history of the two old, large industrial buildings (Mestaritalo and Merikortteli) with their large, cheap and malleable spaces, which attracted the entrepreneurs to the area. These data are secondary. Primary data were gathered through an interview with the founding member and first chairwoman of the Punavuori residential association.

3.2 Data analysis

The statistical data provided objective facts about the area. The secondary data were analysed using the close reading method. Close reading is a broad category of interpretative explorations, which enable a detailed analysis of phenomena (McClennen, 2001).

The analysis was based on the 6T framework of experience. The analysis of words and interpretation of texts was conducted by close reading. A similar analysis has been conducted on the video.

This systematic analysis of the content rather than the structure of a communication included the study of thematic and symbolic elements to determine the objective meaning of the communication. This qualitative research is based on the interpretation of the phenomenon through detailed analysis.

4 RESULTS

4.1 Punavuori experience

Tune. Entrepreneurs and other inhabitants during the organic change process sought a fresh environment and atmosphere. Both the walkthrough and the interviews indicate that Punavuori is a lively area. It had a reputation as a centre for nightlife, but like one interviewee noted, the arrival of the firms in the area also made it alive during the day. There was a diversity of actors associating in the place. Interactions were noted among the remaining industrial workshop workers, local artists and the increasing numbers of media and design professionals. These interactions provided a sense of environment that is dynamic, diverse and full.

At the time of the walkthrough, the area was not lively due to the wintry weather. However, the small design shops and studios were prominent. From the bottom floors of the larger industrial buildings, one could see large advertising agencies. The informal tune of the area could be sensed due to the layers of the buildings from different times that were in different conditions. This area has kept its signs of use and is not trying to look “made-up”. The rough edges are visible. It becomes apparent that in cold weather, the inviting cafés are where the bustle of life is. Even if the area has now become more sober, some old-time vinos still roam about.

Tempo(rality). Punavuori is identified as a place with a history. The interviewed people had many stories connected to it. The buildings have different layers representing styles from different building traditions. Seen from the perspective of time, history was present, but actual time also took place. When the media professionals came to the area, the “current fashion” was changing from “ultra luxury” towards something more “rough” and “fresh”, and Punavuori took on these qualities at that particular moment. The statistical data show that the area has become popular among design professionals.

At least two simultaneous change processes are taking place in Punavuori. The dominant change was that connected to the creative class. The fact that there were already entrepreneurs from the movie industry in the area supported their locating in Punavuori. The entrepreneurs found the area and began to induce other changes. What was earlier designated as a slum was now a vibrant Design District. At the time the media people began to arrive in the area, the residential association also began to form.

Task. Both entrepreneurs and inhabitants have operated in a way that they find the place good enough. There are features and qualities in Punavuori that are fine just as they are. There is no compulsion or incentive to do any major improvement or development projects. The interviews suggest that even though everything does not function in an ideal fashion, people are willing to stay. If a place is attractive to people, they are willing to tolerate it even if it does not function perfectly. In a place with the reputation of being “rough”, these non-functional elements are even considered part of the “roughness.” “This place is not for the wimps and sissies.” Sometimes the attraction of a place can be destroyed by making it look too sleek. “The charm of the place does not rely on encrusted scenic cultural or cafe spaces but on proud entrepreneurship and hard work.”

Tie(s). Having the tune of an informal area with few established rules, many people found it easy to make connections with the place. You could easily familiarise yourself with the area. Additionally, the strong stories of the place allowed people to tie their own tales to the exist-

ing ones. All of the people interviewed had personal anecdotes to relate. As an example, one entrepreneur described the present situation of their office: “Legend tells that it was right here on Pursimiehenkatu, that Nokia made the ultimate decision of going into electronics” (Karvala 2008).

Tale. The Punavuori area tells a story about a rough and lively neighbourhood. It has a distinct reputation. The tales are also ties; there is a set of stories that the residents and the arriving media entrepreneurs shared. The story of Punavuori is about a “rebel” area, which does not provide comfort but is still attractive. In the interviews, this rebelliousness was considered a strong identity of the area. Additionally, during the walkthrough, traces of this roughness told about the past. For a long time, Punavuori had been mainly a working- and lower-class area. The change from industrial to creative entrepreneurs and the ability to afford large, vacant and cheap industrial spaces or small spaces on the ground floors of residential buildings attracted artists to these work spaces and the residents to living space.

(Tenor)Theme. The importance of Punavuori consists of its unique identity, which is significant for diverse actors. It is recognised as an area both for living and working, and it has developed into a Design District with a strong reputation. The investment of time, money and active participation to the development of the area is a theme, which contributes to the people’s willingness to attach to the place. The media entrepreneurs emphasised the “self-made” spirit of Punavuori.

4.2 Points of connection

The 6T-analysis of the data indicated that the experience of the urban area has overlapping elements and is also shared by diverse users. These elements can be called points of connection and include:

1. The informal atmosphere
2. The organic change process as a rhythm of the place
3. The freedom to adopt and find creative solutions for conducting work tasks
4. The ties between living and working
5. The layered narratives
6. The strong identity to be recognised, shared and supported

These points of connection can be investigated further using service design and usability investigations methods, such as user journey and walkthroughs, to extend the experience-based approach and develop links between subjective and objective assessments of urban areas among a variety of users.

5 PRACTICAL IMPLICATIONS

In the context of usability research of built environments, the experience-based framework, namely, the 6T-model, offers a tool to aid in the analysis of diverse user experiences. This framework helps to articulate experiences in a way that, on one hand, bring out their differences. On the other hand, it helps finding the points of connection among people with different experiences. The intention of this paper was to link the often opposite discussions in urban development (creative class development vs. gentrification) by examining users and user experience.

The user experience based framework also provides a tool for discussion about various agendas in the design and planning processes. It can help users and other actors find common and shared points of view. Additionally, the framework can assist place managers, who are developing solutions for a wide range of urban areas. User experience is important in understanding the shifting uses of space, such as hotel-style offices, mixed-use facilities, multi-tenanted places competing for business from property owners, investors, tenants, shoppers, residents, tourists and visitors alike.

6 CONCLUSION

The analysis makes it easy to identify the common points of connection from the perspectives of those working and living in the Punavuori area. The media entrepreneurs and local inhabitants, often artists and designers, have common ways to connect to the stories of the area. Further investigation is needed to examine the variety of individuals in the area and to deepen the understanding of their unique experiences. These rich data will then be reflected in the findings of retrospective data and the two mainstreams of living and working in the organic change process.

REFERENCES

- Alanen, A. (2007), "The network village of design services lies in southern Helsinki", *article is published originally in Finnish at the journal of Statistics Finland TIETO& TRENDIT*, Vol. 14, No. 4-5.
- Alexander, K. (2010), Usability of Learning Environments, in Alexander, K. (Eds.), *Usability of Workplaces – Phase 3* (pp. 5-16), International Council for Research and Innovation in Building and Construction, Rotterdam.
- Alexander, K. (2008), Usability of Learning Environments, in Alexander, K. (Eds.), *Usability of Workplaces - Phase 2* (pp. 5-16), International Council for Research and Innovation in Building and Construction, Rotterdam.
- Alexander, K. and Price, I. (2013), Introduction: space, management and organization, in Alexander, K. and Price, I. (Eds.), *Managing Organizational Ecologies: Space, Management and Organization* (pp. 1-7), Routledge, New York.
- Bennett, A. (2000) *Popular Music and Youth Culture*. London: Macmillan
- Csikszentmihalyi, M. (1990), *Flow: The Psychology of Optimal Experience*, Harper and Row, New York.
- Diller, S., Shedroff, N. and Rhea, D. (2005), *Making Meaning: How Successful Businesses Deliver Meaningful Customer Experiences*, New Riders Press, Berkeley.
- Drake, G. (2003), This place gives me space: place and creativity in the creative industries, *Geoforum*, Vol. 34, No. 4, pp. 511-524.
- Forlizzi, J. , and Battarbee, K. (2004). Understanding experience in interactive systems. *In the Proceedings of DIS2004*, pp. 261-267.
- Florida, R. (2002), *The Rise of the Creative Class: And How it's transforming work, leisure, community and everyday life*. New York: Perseus Book Group.
- Gottdiener, M. and Hutchison, R. (2011), *The New Urban Sociology* (4th edition), Westview Press, Colorado.
- Hakkarainen, H. and Putkonen, L. (1996), *Helsingin kantakaupungin teollisuusympäristöt*, Helsinki City Museum, Hakapaino, Helsinki.

- Jutikkala, E., Hornborg, E., Waris, E. and Castrén, M. (1956), *Helsingin Kaupungin Historia - Osa 5:3*, Finnish Literature Society's Printing Company, Helsinki.
- Karvala, K. (2008), Luova luokka (löytyy tehtaan varjosta), *Maine*, Markkinointiviestinnän Toimistojen Liitto Oy, pp 18-21.
- Lees, L., Slater, T., and Wyly, E. (2008), *Gentrification*. New York: Routledge.
- McClennen, S. A. (2001), "How to do a close reading", available at: <http://www.personal.psu.edu/users/s/a/sam50/closeread.htm> (accessed 27th November 2013).
- Nononen, S. and Kojo, I. (2013). Experience of places – six dimensional model for capturing the user experience, *Proceedings of ECFM13*, May 22-24, Prague, Czech Republic.
- Oliveira, P. (2012), Space and place as user-experience: taking Notting Hill as an example, *International Journal of Business Anthropology*, Vol. 3, No. 1, pp. 62-81.
- Perdikogianni, I. (2007), From space to "place": the Role of space and experience in the construction of "place", *Proceedings of the 6th International Space Syntax Symposium*, June 12-15, İstanbul, Turkey, available at: <http://www.spacesyntaxistanbul.itu.edu.tr/papers.htm> (accessed 27th November 2013).
- Rosén, R., Hornborg, E., Waris, H. and Jutikkala, E. (1956), *Helsingin Kaupungin Historia - Osa 4:2*, Finnish Literature Society's Printing Company, Helsinki.
- Rosén, R., Hornborg, R., Waris, E. and Jutikkala, E. (1955), *Helsingin Kaupungin Historia - Osa 4:1*, Finnish Literature Society's Printing Company, Helsinki.
- Rosenbaum, M. S. & Massiah, C. (2011), An expanded servicescape perspective, *Journal of Service Management*, Vol. 22, No. 4, pp. 471-490.
- Schulman, H. Pulma, P. and Aalto, S. (2000), *Helsingin Historia Vuodesta 1945 - Osa 2*, Edita, Helsinki.
- Shedroff, N. (2009), *Design Is the Problem: the future design must be sustainable*, Rosenfeld Media, New York.
- Shields, R. (1991), *Place on the margin: alternative geographies of modernity*, Routledge, New York.
- Tähtinen, S. (2013), An interview with Pirjo Tulikukka on 7th March 2013.
- Tuan, Y-F. (1977), *Space and place: the perspective of experience*, University of Minnesota Press, Minneapolis.
- Turpeinen, O., Herranen, T. and Hoffman, K. (1997), *Helsingin Historia Vuodesta 1945 - Osa 1*, Edita, Helsinki.
- Xiaowu, H. (2006), *Research of Urban Value and Development System*, China Southeast University Press, China.

7.2

THE USERS' RELOCATION PROCESS: A UNIVERSITY FACULTY'S STAFF EXPERIENCES

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ABSTRACT

Purpose: This study identifies the psycho-social factors that impact on individual users' unique relocation experiences.

Background: Relocation studies often focus on the effects of changes in the workplace on a homogenous group called 'employees'. However, relocation is more than a 'before' and 'after' state on either side of a move event, it is a process. Further, all users are different and also experience the process uniquely.

Approach: This study investigated the users' experiences of a university faculty's relocation. Within a case study approach, a constructivist ontology was adopted where the users' experience was taken as being psycho-socially formed. Data collection included recording project events, interviews (10% of employees), diaries to record experiences as they happened (another 10%), and participant observation as two of the researchers were themselves relocated. The textual data was thematically coded using Atlas.ti software.

Results: The findings show how different individuals can experience the same new space, or the same process, in different ways, depending on various individual characteristics. The main psycho-social variables that influenced employee experiences in this study are previous experience of space and relocation processes, employment basis, and personality and life situation.

Practical implications: All relocations' aspects require attention in managing relocations. In particular, because individuals have unique relocation experiences, more nuanced relocation practices are necessary. While practically difficult to manage as individuals, they are a matrix of various psycho-social factors and provided all the factors are attended to then connections with individual's characteristics should occur

Research limitations: The qualitative study has unique characteristics that constrain its generalizability. However, facility management theory still benefits from studying FM's relocation practices.

Originality/value: This study conceptualises relocation as space, process, and individuals. It contributes to understanding how individual users' unique relocation experiences are formed by identifying documenting psycho-social factors that impact on those users' experiences.

Keywords: Australia, Facilities management practice, Relocation, User experience

1 INTRODUCTION

Relocations are significant for organisations, even when relocating in the same neighbourhood, town, or metropolitan area. These short distance relocations where employees do not have to change residence are the most common form of relocation. Various reasons prompt relocation but seeking positive organisational outcomes is very common. Usually relocations are conceptualised and studied as changed:

- Responses to the physical workplace – before and after the relocation event;
- Work process and business outcomes from the new workplace environment; and
- Organisational arrangements, culture and the like related to the different environment.

Relocation practices also impact on those experiencing the relocation. Many practices employed at this time relate to the new workplace's spatial production and are very frequently studied in relation to both the production processes and the new environment. It is rarer to study the relocation process itself which comprises the act of physically moving (which may be seen as an 'inconvenient truth' in getting to the new end state), preparing to move and settling in afterwards. This makes the process much more than just moving, which can be quick, for instance in a weekend. These relocation practices can affect assessments of the relocation experience and, by extension, the organisation itself. For knowledge intense organisations, their employees' assessments are very important because they are significant business resources which create organisational outcomes. This suggests that individual employees' experience of relocations is as important as the ones they have of the organisation.

2 STATE OF THE ART

Previous research, such as Morgan and Anthony (2008), identifies many positives from changing workplace, such as desirable behavioural changes, enhanced employee experiences and productivity, and reduced accommodation and human resources costs. Studies conducted within a relocated setting do, in fact, often focus on identifying this change in users' experiences in the new space compared the old space, often using some type of Post Occupancy Evaluation (POE) (for example, Brennan et al. (2002), Brown et al. (2010), Riratanaphong and Voordt (2012), and Spreckelmeyer (1993)). The Dutch Center for People and Buildings has developed a toolkit consisting of different tools performing POEs which evaluate not only user satisfaction, but also perceived labour productivity, as affected by different workplace strategies. The tools can be used before an accommodation change as a baseline measurement, or after an accommodation change (Maarleveld et al., 2009).

Even though more holistic forms of POEs, which also address psycho-social factors (such as personal history and characteristics), have been called for (Turpin-Brooks and Viccars, 2006), these kinds of studies play a crucial role in increasing the understanding of the effect of dif-

ferent workplace solutions on employees and the organisation, which is vital in guiding facilities professionals when developing new work environments.

However, achieving a successful work environment is not only a matter of creating a successful space; it is also a matter of implementation. The FM-related literature on accommodation and organisational change emphasises successful change being achieved by things like communication to, engagement with and participation by those undergoing the change (for example, Bull and Brown (2011; 2012), Laframboise et al. (2003), Milligan (2003), and Vischer (2011)) What these processes are intended to produce are more favourable or optimised responses to the changed environment. This literature focuses on instrumental change management knowledge that is useful to facilities practitioners. These processes are, however, external to the users who are seen as objects of change while often being treated as a homogenous group called ‘the employees’.

Meanwhile, the change management literature has also shown that individual differences influence change acceptance (Bareil et al., 2007; Wanberg and Banas, 2000). Within the FM literature, evidence of this kind is rather scarce. Vischer (2011) suggests that people at different levels and in different functions react differently to the idea of workplace and organisational change, while Bull and Brown (2011)’s survey found a difference in the preferred communication method between back office and customer service staff. Yet, studies that look at the process of relocation from the perspective of the individual user still seem to be lacking.

To conclude, relocation studies usually focus on the effects of the workplace. Further, the literature suggests that successful implementation of a new workspace setting requires change management actions, such as communication, engagement and participation. However, how individual differences affect the user’s experience of both space and the process has yet been undocumented in previous literature. If research is to better uncover the users’ experiences of relocation, studies need to not only look at employees as objects of change, but to understand the entire relocation process from their perspective. All users are different, hence, it is suggested that identifying the psycho-social factors that impact the individual user’s experience can help understanding how relocation experiences are formed. In order to more directly capture the experiences of relocation this study used the opportunity afforded by a university faculty’s relocation to examine the experiences of the users while they were actually occurring.

3 APPROACH

A case study approach (Yin, 2009) was adopted for this study of a knowledge intense organisation (a university faculty) relocating to temporary facilities to allow construction of a new building on its old site. The relocation event was spread over several months in the second half of 2012, for example the library moved mid-year, some professional staff moved mid-semester and the main move was at semester end in November 2012.

Arguably, this relocation process commenced when a new faculty building was mooted in early 2008. This gave users a pre-figuring awareness that a whole-of-organisation relocation would be required should the project come to fruition. This awareness firmed as the project developed and relocation became certain when a formal commitment was made to rebuild. This also meant two moves would be involved – into the temporary facilities and into the

permanent facility. This study only reports the first event. While many facility management actions were recorded pertaining to the new building from early 2008 onwards, specific relocation actions can be identified in the second half of 2011. This is over 12 months before the main move.

The approach adopted is a user-centred one (Vischer, 2008) where the complex nature of the relationship between management of the environment and users suggests that it is useful 'to go directly to users and question them on their own view and definition of experience, making use of subjective user experience and using an objective approach in doing so' (Vischer, 2008, p.236). This underpins the research methods used and described below. Because of this user-focus, the case study focussed on relocations' psychological and social dimensions. Consequently, a constructivist ontology was adopted where reality is constructed, or emerged from, the users' psycho-social factors.

This study's users are the faculty's staff – academic (A) and professional (P) employees. Student users were studied in a separate project. Participants (20 % of employees) were selected randomly from both staff groups in proportion to the size of each staff group. This resulted in 16 academic and 14 professional participants. We excluded senior faculty management and others involved in the project as these constitute the faculty's facility management actors that were creating the user experiences. Also excluded were the two authors who experienced the relocation. As we had no influence in planning the relocation or the new building the research approach could not constitute action research. Rather, in addition to the data collection and analysis described below, a form of participant observation was used where we were no more or less involved in the relocation than the study's participants. This was to avoid biasing those participants and to still gain valuable interpretive insights into the users' experiences.

Data collection included recording project events, interviews (8 academics; 7 professional), and diaries to record experiences as they happened (another 8 academics and 7 professional). The interviews were done in two phases: before (b) and after (a) the move. The interviews were recorded, transcribed and sent to respondents for checking. The diaries were sent out before the move (1-2 diary entries, depending on move-date of the respondents) and after the move. The focus of both interviews and diaries was on the participants' understanding and thoughts of the process and the space, with questions starting on a more general level (for example, "Please describe in your own words what has so far happened in the relocation process" and "In your own words, please briefly describe your current thoughts about the relocation") with more detailed questions (for example, "How do you feel about your possibilities to participate in relocation related activities?") asked to ensure all aspects of the relocation were covered. The textual data was then analysed using Atlas.ti software. First, the data was coded with codes of descriptive nature which means they included little interpretation (Miles and Huberman, 1994). Instead, they served the purpose of describing and summarizing what the participant had said. During the coding process, notes were taken of things that emerged which had influenced the participants' experience of relocation. Subsequently, the codes were used to retrieve the relevant quotes which were then arranged into themes which can be seen in the two right-hand columns in the findings tables, below.

4 FINDINGS

Based on the interviews, the actual relocation event can be described as being quite successful. The interviewees were unanimously of the opinion that the Faculty's Facilities team had done a remarkable job in planning, coordinating and communicating about the move. Also,

the new, temporary building and workspaces were found to be good, and most participants were quite happy about spending the next two years there. Many participants were of the opinion that the new working environment had had positive effects on them and the faculty at large; an increase in spontaneous interaction and communication within the faculty was mentioned by almost all participants, though some of this could also be attributed to the share relocation experience.

However, a thorough analysis of the users' relocation experience disclosed how different psycho-social dimensions impacted on the individual user's expectations of and satisfaction with both the relocation process and new space. Next, these dimensions will be presented one at a time, with illustrative quotes presented in the respective tables.

4.1 Impact of previous space experiences

First, it became evident that the individuals' previous space experiences impact on their expectations and satisfaction with especially the new space, and also with the process. When asked about expectations of the new space, participants often grounded their expectations in the space they were currently occupying. Subsequently, the new space was assumed and hoped to comprise, at a minimum, the same functionalities as the currently occupied one and to be of the same, or better, standard. Likewise, satisfaction with the new space was often expressed in relation to the previous space. Interviewees post-move were satisfied with the new space because it was considered better than the previous. This suggests that things which have already been received and experienced become expected with time. Further, it seemed that there was a level of understanding for negative issues in the new space when the problem had been present also in the previous space, as in an example where issues with air conditioning were not considered significant as the air conditioning did not function well in the previous space either.

The impact of the previous space on individual users' experience of the new space was also demonstrated by two different users' comments about their new work environment. Despite being located along the same corridor in the new building, these two participants had completely different views on the level of interaction in the new space. While one thought that it was great that the new space facilitated interaction and running into new people, the other expressed a worry that interaction was not as spontaneous anymore. Moving from two separate buildings into one did bring the entire staff closer together, however, the contradicting experiences of these two participants can be explained by the difference in the amount of interaction these participants were used to in their previous settings – in different buildings.

While the impact of the old work environment on users' experience with the new space is somewhat manageable for facility managers, the impact of users' previous space experiences poses a bigger challenge. The interviews showed how users might set expectations on their space based on what they have previously experienced elsewhere, and how previous space experiences also influence their satisfaction with the new space.

Table 1: Impact of space experiences, illustrative quotes

Illustrative quotes	Impact of	Impact on
“[Layout will be] Pretty similar I suspect to what's there now.” (P/b) “I think there's like a kitchen facility, which is good because we have that here so it's, you know, we need to have everything that we have here over there” (P/b)	Old space	Expectation of space
“It was great. You sort of feel a lot more organised. You know where things are now.	Old space	Satisfaction

<p>So, it's actually a really good space compared to our last place, It's a lot bigger and the storeroom's just next door so it's fairly handy." (P/a)</p> <p>"It's a lot bigger space, it's just a lot easier to work in the new space than it was previously because we were all kind of bundled on top of each other so just in terms of I guess allocating the space to the particular departments I think has been done quite well." (P/a)</p>		with space
<p>"Yeah it's [interaction with academics] definitely not as spontaneous and it's not as easy to facilitate and I think the risk is further down the track that will become further removed as we move on." (P/a)</p> <p>"You kind of see academic staff more often now which is great. You run into people more often rather than being so separated from them. No, it's a really good building, really workable I think for us. Just being close to everyone is great." (P/a)</p>	Old space	Impact of space
<p>"I'm excited. I think it's going to be really good. Like I said, this building is cold and old and, you know, I can't wait to get out! I can't wait to get a bit more space. Just kind of like even going to a space that that's just my own, so you can kind of make your own of it because everyone's kind of going in at the one time. So yes, I'm really excited." (P/b)</p> <p>"I'm not really attached to the buildings as they are now so I'm quite happy to move." (P/b)</p>	Old space	Feelings about relocation
<p>"We can live with it for two years but I expect to have art in the new building and tasteful art because I know that you can – where I come from we had an art collection that would be rotated so that would be really nice so you can choose your own artwork and then it would be rotated within the university." (P/a)</p>	Previous space experiences	Expectation of space
<p>"Also I'm - it's probably because I've got my own cell and I'm quite happy with that. It's fine. I'd probably feel differently if I'd been lumped in a cluster, which I think a few people have. But it suits - it will be fine. Because I can also think back to what it was like at [name of previous University] and it's still fantastic. I think it seems like there's not a bad view from the window." (A/b)</p> <p>"Well, you know, when I was doing my PhD, we had a big relocation in the US which I was in, and everybody was put in these cattle sheds in open fields so, compared to that, I guess this is pretty good, so I've been through worse." (A/b)</p>	Previous space experiences	Satisfaction with space
<p>"I just remember coming along and even the light fittings didn't work in the corridors and it was Winter, it was after five and it was just like "God, this place is horrible. What did we do to deserve this, being stuck in here?". So I wasn't really looking forward to that, coming here, and then when I got here, obviously they've kind of brightened it up quite nicely." (A/a)</p> <p>"I was expecting it to be really isolating and grey because it had been my experience in this building and I wasn't looking forward to it, so you know, that's really exciting." (P/a)</p>	Previous experience of the new space	Expectation of space
<p>So I was here for 12 years and it was great, because there was all this music playing. It was a lovely art atmosphere. So I'm really happy to be back. " (A/a)</p> <p>"[The architects] have done a great job I think. I've studied in this building before and it used to be very drab and the macabre grey and they've just lightened it up. Obviously they're restricted by the confines of the building itself but I think it's a much better area than it was two, two and a half years ago when I studied here. [...] I think because they've lightened it, the feel to it, it does feel bigger than it was, it's got that effect where you walk in and think it's a small building, each level is cramped but it's a bigger feeling." (P/a)</p>	Previous experience of the new space	Satisfaction with space

Further, a phenomenon quite specific to this case occurred where users' previous experiences with the space they were moving into impacted their expectations. Several participants had previously worked or studied in the building to which the faculty relocated, and while one participant had previously found the atmosphere in the building very pleasant and was look-

ing forward to going back, others remembered the building as grey and dark, and were therefore not enthusiastic about relocating to this specific building.

4.2 Process experience

The interviews revealed that also previous process experiences influence how users feel about relocation (Table 2). Even though the relocation of the faculty turned out to be efficient and well organised, participants admitted that they expected or had expected the relocation to be “painful” or “messy” and “dreading” the relocation because of previous experiences either with the university, or elsewhere. A number of illustrations were given by the interviewees also of how previous experiences with communication and participation possibilities impacted expectations of the same. Good practices that had been experienced elsewhere were anticipated also in this relocation.

Table 2: Impact of process experiences, illustrative quotes

Illustrative quotes	Impact of	Impact on
<p>“I think it's going to be a painful - I think it will always be painful. I think - I mean, I have a - I just - I'm informed by my previous experience of moving in this faculty.” (A/b)</p> <p>“It just that I have been in another - when I was doing my PhD we had a building construction problem and we had to re-locate it to another building, and it was such a messy re-location that I thought it would be like that and I was dreading it, it was so inefficient.” (A/a)</p>	Previous experience of relocation	Expectation of process
<p>“I've worked with organisations that have 2,000 plus staff and there, maybe, you need to be general [in communication] but when there are 150, say, I think it's possible [to be more personal]” (A/b)</p>	Previous experience of communication	Expectation of communication
<p>“So it would have been nice to [participate], because like when we moved – when I was at the University of [name of University], we had a committee that decided on the paint colour of the rooms that we were going to have – paintings, lightings and the general feel of it. So that was nice. Yes, that was good to have that. It helped us also have ownership of the new building and camaraderieship as well. So that was good to be involved in that part.” (P/b)</p>	Previous experience of participation	Expectation of participation

4.3 Employment basis

Various employment-related aspects that could be linked to the participants' experiences emerged from the data. First, space expectations seemed to be impacted by the individuals' attachment to the organisation. Those appointed on a casual or part-time basis expected less of the space they would be allocated, compared to more permanent colleagues, and they often also did not expect to be given an opportunity to give opinions or share ideas about the new space. This was also shared by those who identified themselves as being in the lower levels in the organisational hierarchy.

Being part-time also, very practically, affected at least one individual's experience in regard to awareness of what was going on. A lot of the relocation-related information was communicated during monthly staff meetings; but these always occurred on the same weekday, which happened to be a day when this participant did not work. Another practical impact of participants' employment basis on their relocation experience was found in the amount of things they had to be relocated. In general, compared to the professionals, the academics had gathered a lot more documents, books, research material, student works, and the like, that had to be relocated. As a consequence, professionals seemed a lot less stressed about packing and moving. While one member of the professional staff explained how the relocation will be very easy due to the small amount of things they needed to move, many academics anticipated

ed many hours of cleaning and packing. Though, some saw this as an opportunity to throw things out for a fresh start in the new building.

Table 3: Impact of employment basis, illustrative quotes

Illustrative quotes	Impact of	Impact on
“I think being casual you sort of do tend to stand back a bit and – you know, as long as you’ve got a desk and a job you’re quite happy!” (P/b) “I’m a Web developer so all I really need is internal access and a computer and I’m fairly happy.” (P/b)	Employment basis	Expectation of space
“Oh, yeah, it’s funny, structurally we’re not in a position to give our opinion so that’s okay, that’s what you expect. So, that’s fine.” (P/a) “Well, the role I had before I don’t think they needed to ask me” (P/a) “I’m not really thinking I’m going to be in this department in 10 years’ time teaching, so I don’t need to have input into my workspace.” (A/b)	Employment basis	Expectation to participate
“I know there have been lots of staff briefings; I know there have been lots of feedback sessions. I don’t work on the days when they’re on so I haven’t been able to go to them” (A/b)	Employment basis	Awareness
“It’s easy for me; I don’t have a lot of stuff that I’ve accumulated over years and years, and I don’t have research groups or research stuff to relocate. I can imagine it’ll be tougher for them. But for me I’m probably one of the – for me it’s probably the easiest out of anyone really. [...] I’m a data analyst, you know, so I would have a box-full whereas someone – and I know some of the academics would have twice as much the stuff as that. So yes, I’m feeling okay with the move, so yes [...]”(P/b) “I have some negative feelings toward relocation since it means that I need to continue to go through and organize the piles of paper in my office. I began to throw stuff away at the beginning of the semester, and realize that if I do it in small bits over time, the job will be less tedious, however I have been smashed with work this semester and do not see myself re-commencing with my office clean up until mid-Oct.” (A/b)	Amount of things	Expectation of process
“[Relocation was] Good. I didn’t have a lot of stuff to move so I just had one crate. That’s all I had.” (P/a)	Amount of things	Satisfaction with process

4.4 Personality and personal life situation

The participants gave several illustrations of how personality and personal life situation were important in the relocation experience. It should be noted that the different personality traits were those mentioned by the participants and that this study did not include any form of personality test. Being someone who is “adaptable”, “tries to live in the moment” or “weaves with the flow,” in general, also reflects onto how users thought of relocation. These rather easy-going persons did not worry much about what the new space would be like and they considered that it will all turn out well in the end. Those persons who admitted to being a bit “picky” felt concern about the new space before relocating. Personality differences also impacted expectations of communication: the “hands-off” person and those who found change exciting were happy not to know every detail about what was going on, while others wanted all the necessary information available.

In addition to personality, there were examples of how personal life situations can influence space expectation and relocation experiences. One participant commented how shared office space is a great office solution if you have a home with a private study where you can have your quiet writing time, but that this is not the case if you are in a life stage where there is not a quiet area in your house. Additionally, for two participants the faculty relocation happened to coincide with their own residential relocation. This caused a bit more “trauma” and made

the time around the relocation even more stressful for these participants than it would otherwise have been. This invites speculations to how other types of significant life events might impact users' experience.

Table 4: Impact of personality and personal life situation, illustrative quotes

Illustrative quotes	Impact of	Impact on
<p>"I'm one of these people that sort of tries to live in the moment and I don't really have any expectations. [...] I'm quite an adaptable sort of person. I expect it'll be fine. It may even be better. Like I don't think it'll be worse – put it that way. But I, you know, you just go with the flow." (P/b)</p> <p>"I don't worry about these things. I just do it when it comes. If you worry about it – I just weave with the flow. That's the only way to do it for me." (A/b)</p> <p>"I have a couple of reservations but that's just because I'm a bit picky. I'm a bit concerned that the new building didn't look like it was at the point where I could move in just yet." (P/b)</p>	Personality	Expectation of space
<p>"About the relocation itself? I don't feel unsettled by it. You know, like you just have to go with whatever happens. I'm quite an easy-going person I think so I don't really have any – sort of change is always exciting." (P/b)</p> <p>"No [there's nothing I would have wanted more information about], but my personality is very much hands-off, not a control freak." (A/b)</p> <p>"I prefer to know. I'd rather, I mean a lot of it would have been email communication so you can always choose whether or not you want to read that but at least then they've done it, that kind of way. So, if you are wondering what is this about you can go and read your email and oh yeah, they did tell us about that last week. You know, so I'd rather know." (P/a)</p>	Personality	Expectation of process
<p>"You know, if you have a nice big house with a private study, maybe you want to come to work and hear everyone talking about stuff all of the time, and when you want to do some quiet writing, do it at home. But that's not where I'm at. I don't have a nice, quiet writing spot at home unless it's the lounge room after everybody's in bed." (A/b)</p>	Personal life situation	Expectation of space
<p>"I've moved a few times now and I really do hate it and I think at the time, I was also moving house so it was probably a bit more of a trauma to have to move house and move office, but I think comparing to moving house, it was pretty nice." (A/a)</p>	Personal situation	Process satisfaction

4.5 Discussion of findings

While previous studies often approach relocations as a change in workplace setting, this study proposes that relocation is more than a 'before' and 'after' state on either side of a move event. Thus, this study looks at relocation within a larger conceptualisation of the phenomena as space, process, and individuals.

From the users' perspective, relocation is a process that begins, at the latest, when the idea is initially brought forward, and which has an indistinct end as it might still impact the space experience for a long time ahead. Seeing relocation as more than just a space change was also supported by the participants' responses when asked about their general thoughts about the relocation: some brought up the future space, others started talking about process-related issues, while one interviewee made a reference to how this event is related to the yet-to-be-built faculty building.

A review of the relocation and accommodation change literature shows that, when seen as a change process, studies have often focused on the effect of management actions on the experience of a homogenous group called 'employees'. However, all employees are individuals who have their own unique experience. As the findings demonstrate, two individuals from the same predefined staff group can experience the same new space, or the same process, in dif-

ferent ways, depending on various individual characteristics. This study contributes to the understanding of how these unique relocation experiences are formed by identifying and documenting psycho-social factors that impact on users' experiences as individuals. The analysis shows that there were five main psycho-social factors contributing to users' experiences:

- Previous experiences of:
 - Space, where the experiences were of the old space being vacated;
 - Space, being a previous experience of the new space or other spaces;
 - Relocation processes;
 - Communication about the process; and
 - Participation;
- The employment basis;
- The amount of things (to be relocated);
- Personality; and
- Personal life situation.

All the psycho-social factors, except the 'amount of things,' impacted on expectations of the new space, but only the various previous space experiences impacted on satisfaction with the new space. All the variables except 'personal life situation' impacted on expectations of the process. However, it was the 'amount of things' and the 'personal life situation' that impacted on the satisfaction with the process. It should be noted that the amount was, in this instance, the small amount of things (only one crate) that made it a satisfactory process. The study's respondents did not include those that had a very large number of crates of things (several relocators had over 80 crates and the maximum was in excess of 100). They may have expressed a different satisfaction. Nevertheless, the relationship between amount of things and process satisfaction remains.

Expectations of participation and communication were both impacted on by previous experiences of them and the employment basis (part-time) lead to lower expectations about participation and lower awareness of what was going on through missing scheduled briefing sessions.

5 PRACTICAL IMPLICATIONS

Facilities managers already engage practically with relocation. However, relocation is often seen as a challenge of transition from a before state to a new, more desirable, and more effective, after workplace state. Change management is necessary in getting to and optimising that end state and moving is an 'inconvenient truth' in getting to that new workplace. However, this study reconceptualises relocation as a more holistic process consisting of: change in the physical environment; the two processes of achieving space change and of moving; and the individuals that experience and assess the environments and the processes.

The practical implications are that all aspects of relocation require attention in the transition and in attaining satisfaction with relocation. This is because it is evident in this study that all relocation aspects contribute to the users' experiences that are a basis of satisfaction. Because it is individuals that have relocation experiences this suggests that more nuanced relocation practices are necessary. This is because those individuals bring histories of previous relocations and experiences of space that shape expectations for this time, current life circumstanc-

es, personalities, and amount of things to physically relocate. While practically difficult to manage at the individual level, the aggregate level of analysis in this study shows a range of psycho-social factors where specific attention can be paid. Discrete individuals will be a matrix of these factors and provided the factors are all attended to then connections with individual's characteristics should occur.

6 CONCLUSION

This research contributes to the user-centred theory of the built environment, particularly its management practices, as the relocation process is the object of study. Here the relocation is conceived as a multi-dimensional phenomenon that is rarely studied in its entirety. Rather, previous research has focussed on parts of the phenomenon, most often the workplace as before and after states either side of a move event. What was evident from the review of the literature is that while having a principled concern for people's involvement with and experience of change there is, as yet, a tendency to assume undifferentiated users and to inadequately conceptualise the fundamental basis of people's experience of this relocation.

The study shows that users' experiences of relocations are fundamentally psycho-socially formed and that these contribute to unique experiences for those that are facilities management's space and service users. This paper's findings then adds significantly by documenting detailed psycho-social factors in users' experiences of relocation. This is important for a discipline that so clearly places 'people' centrally in its rationale for existence and the value that it adds.

This addresses a gap in facilities management theory and suggests that those managing relocation and other facilities' change need to better understand these psycho-social factors in managing relocation processes. The impact of the old work environment compared with the new is relatively manageable and relatively well theorised. A bigger challenge is users' previous experiences of processes as well as space. Understanding and incorporating them into relocation practices suggests further investigation of those background experiences as an input into managing relocations and into understanding the bases of satisfaction with relocations.

This research relied on the self-identification of the impacts in the users' experiences. This is appropriate for this exploratory study. Based on this research, future research could develop an expanded body of potential impacts, other types of facility users, and more directly examine causal and quantitative relationships.

ACKNOWLEDGEMENTS

We wish to acknowledge the contribution of the project's funders – Tekes in Finland and the Faculty of Architecture, Building and Planning's New Building Research Fund.

REFERENCES

- Bareil, C., Savoie, A. and Meunier, S. (2007), "Patterns of Discomfort with Organizational Change", *Journal of Change Management*, Vol. 7 No. 1, pp. 13–24.
- Brennan, A., Chugh, J.S. and Kline, T. (2002), "Traditional versus Open Office Design", *Environment and Behavior*, Vol. 34 No. 3, pp. 279–299.
- Brown, Z., Cole, R.J., Robinson, J. and Dowlatabadi, H. (2010), "Evaluating user experience in green buildings in relation to workplace culture and context", *Facilities*, Vol. 28 No. 3/4, pp. 225–238.
- Bull, M. and Brown, T. (2011), "Implementing Change", in Finch, E. (Ed.), *Facilities Change Management*, Wiley-Blackwell, pp. 108–122.
- Bull, M. and Brown, T. (2012), "Change communication: the impact on satisfaction with alternative workplace strategies", *Facilities*, Vol. 30 No. 3/4, pp. 135–151.
- Laframboise, D., Nelson, R.L. and Schmaltz, J. (2003), "Managing resistance to change in workplace accommodation projects", *Journal of Facilities Management*, Vol. 1 No. 4, pp. 306–321.
- Maarleveld, M., Volker, L. and van der Voordt, T.J.M. (2009), "Measuring employee satisfaction in new offices – the WODI toolkit", *Journal of Facilities Management*, Vol. 7 No. 3, pp. 181–197.
- Miles, M.B. and Huberman, A.M. (1994), *Qualitative Data Analysis: An Expanded Sourcebook*, SAGE Publications Inc, 2nd ed.
- Milligan, M.J. (2003), "Loss of site: organizational site moves as organizational deaths", *International Journal of Sociology and Social Policy*, Vol. 23 No. 6/7, pp. 115–152.
- Morgan, A. and Anthony, S. (2008), "Creating a high-performance workplace: a review of issues and opportunities", *Journal of Corporate Real Estate*, Vol. 10 No. 1, pp. 27–39.
- Riratanaphong, C. and Voordt, T. van der. (2012), "Performance measurement of workplace change: A comparative analysis of data from Thailand, The Netherlands and Finland", in Jensen, P.A., Voordt, T. van der and Coenen, C. (Eds.), *The Added Value of Facilities Management: Concepts, Findings and Perspectives*, Polyteknisk Forlag, Lyngby, Denmark.
- Spreckelmeyer, K.F. (1993), "Office Relocation and Environmental Change", *Environment and Behavior*, Vol. 25 No. 2, pp. 181–204.
- Turpin-Brooks, S. and Viccars, G. (2006), "The development of robust methods of post occupancy evaluation", *Facilities*, Vol. 24 No. 5/6, pp. 177–196.
- Vischer, J.C. (2008), "Towards a user-centred theory of the built environment", *Building Research & Information*, Vol. 36 No. 3, pp. 231–240.
- Vischer, J.C. (2011), "User Empowerment in Workspace Change", in Finch, E. (Ed.), *Facilities Change Management*, Wiley-Blackwell, pp. 123–136.
- Wanberg, C.R. and Banas, J.T. (2000), "Predictors and Outcomes of Openness to Changes in a Reorganizing Workplace", *Journal of Applied Psychology February 2000*, Vol. 85 No. 1, pp. 132–142.
- Yin, R.K. (2009), *Case Study Research: Design and Methods*, SAGE Publications Inc, 4th ed.

7.3

USABILITY BRIEFING – A PROCESS MODEL FOR COMPLEX BUILDINGS

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ABSTRACT

Background: In complex buildings with many types of users it can be difficult to satisfy the numerous, often contradictory requirements. Research in usability mostly focuses on evaluating products or facilities with users, after they were built. This paper is part of a PhD project “Usability briefing for hospitals”, where methods for capturing user needs and experiences at hospital facilities are investigated in order to feed into design processes and satisfy the users’ needs and maximise the effectiveness of facilities.

Purpose: This paper introduces the concept of *usability briefing* and the purpose is to develop a process model for applying it on complex building projects. Usability briefing is a process in which users are actively involved, not only in evaluations and data gathering, but also in a continuous briefing process with focus on usability.

Approach: The model is inductively developed from a literature review and three case studies at hospitals in Denmark and Norway. With the aim of connecting to practice, the steps in the model are based on RIBA’s planning phases from 2013.

Results/ Originality: The paper presents an integrated usability briefing process model for continuous briefing, combining the four interrelated activities of 1) briefing, 2) user involvement, 3) evaluations and 4) design. The model provides a visual overview of the four activities in all the building design phases. The approach combines continuous user presence, co-creation, design and evaluation with various users/stakeholders, using creative boundary objects at workshops.

Practical Implications: The research results have relevance to researchers, client organisations, facility managers and architects planning new complex facilities.

Research limitations: The proposed model is theoretical and needs to be applied and further tested. Because of the empirical results, the explanation of the process model focuses mostly phase 1 and 2 of the RIBA planning model.

Keywords: Usability briefing, Users, Hospitals, Evaluation methods, Facility Management

1 INTRODUCTION

In complex buildings with many types of users, like hospitals, it can be difficult to satisfy the numerous, different and often contradictory requirements of all users. In Denmark, this issue recently got much attention because there are currently large number of hospital building and development projects being planned, to be realized over the next 10-15 years. Most of these projects are still in the early stages and the question is what can be done to ensure that the end results will be excellent hospitals that score high on usability, supporting the needs of future patients, healthcare professionals and society.

Most research on usability focuses on evaluating products or facilities with users, after they were built. Evaluation methods include Post-Occupancy Evaluations (POE) and so-called “walk-through” evaluations. This paper is part of a PhD project “Usability briefing for hospitals” which focuses on the issue of usability before the buildings are built. It looks at methods for capturing user needs and experiences in the early stages, in order to provide information to the design processes and thereby try to make sure that the eventual design satisfies the user needs and maximises the effectiveness of the facilities.

The paper introduces the concept of ‘usability briefing’ and a process model for how to include usability briefing in complex projects such as hospital buildings. Usability briefing is a process in which users are actively involved not only in evaluations and data gathering, but also in a continuous briefing process with focus on usability.

The concept of usability briefing has not been thoroughly described in the relevant literature before, although the concept and need for further research was mentioned recently by Jensen et al. (2011). Briefing has been referred to as means to achieve usability (Blakstad et al., 2010, Jensen, 2010), but has not been elaborated as such.

The focus of this paper is on developing a process model for usability briefing of complex buildings with many types of users, and investigates how usability can be incorporated in the early stages of the project, with the aim to create better architectural design for supporting the users and their effectiveness, efficiency and satisfaction. The model is inductively developed from a literature review and from three hospital cases in Denmark and Norway.

2 STATE OF THE ART

The two main concepts, usability and briefing, will be described as a theoretical base, that is further developed in order to develop the concept of usability briefing and a process model for it. Four related concepts will be described: evaluation methods, user involvement, user driven innovation and boundary objects.

2.1 Usability

The concept of usability has its roots in evaluations of consumer products and user interfaces of computer software. In ISO 9241-11 it is defined as: “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (ISO, 1998).

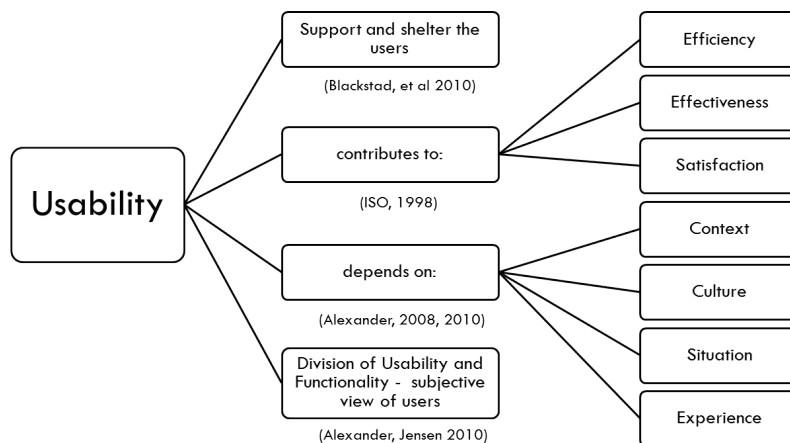
In the field of Architecture the Usability concept is in principle well known since it was already mentioned in ancient Rome by Vitruvius (80-15 BC) in his book *De architectura*, also

known as *The Ten Books on Architecture*. He writes, that architecture must exhibit the three qualities of *firmitas*, *utilitas* and *venustas* - which means that it must be solid, useful and beautiful (2006, 1914). However, understanding and interpretation of his wording is though constantly changing. Moreover, the terms utility, or usability, are often translated to a widely used term in architecture: functionality. Architectural publications describe a functional quality of a building as “its ability to fulfil the functions envisaged for it” (Van der Voordt and Wegen, 2005). Some researchers prefer to make a distinction between functionality and usability (Alexander 2006, 2008, 2010, Jensen 2010, Fronczek-Munter, 2011), where functionality in the building industry is objectively measurable, while usability introduces the subjective views of the users. The result of this is that usability can be evaluated or designed differently by different groups of users.

Blakstad et al. (2010) refer to usability of buildings in their statement that: “A building’s true purpose is to support and shelter its users, while they are performing their activities and living their lives. (...) The physical surroundings contribute to efficiency, effectiveness and satisfaction in the user organisations”. During the last years, researchers suggested extending the concept to also cover the context, culture, situation and experience (Alexander, 2008, 2010). It is suggested that understanding those factors might be achieved by involving users.

The divergence in how usability is understood by different groups is schematically shown in Figure 1.

Figure 1: Overview of the different understandings of the concept of usability.
Adapted from Fronczek-Munter (2011)



2.2 Briefing

Briefing, also called programming in some countries, is usually understood as one of the first phases of a building project, before the design activities start. Guidelines in both Denmark and the UK, name it as the first or second phase of a building project (RIBA, 2013, DANSKE ARK/ FRI, 2012).

Briefing is a process that in practice often results in briefing documents (the brief, or the program of requirements) that contains the client’s requirements for the building. When finished, the document is handed over to the design team who is then expected to translate it into a design proposal. This rather static, document based understanding of briefing has been labelled as traditional and is challenged by several researchers. Their suggestions for change

can be grouped into two views: 1) Briefing should be dynamic (Nutt, 1993, Prins et al., 2006). 2) Briefing should be a continuous process (Barrett and Stanley, 1999, Blyth and Worthington, 2001, Fristedt and Ryd, 2004, Voordt and Wegen, 2005, Jensen, 2006 and Jensen et al., 2011).

Furthermore, it is suggested in literature that there is no such thing as the brief, but several different briefs with different purposes. For example, Nutt (1993) proposes the need for a strategic brief and a facilities management brief. Likewise, Fristedt and Ryd (2004) complement the strategic brief in the pre-project phase with a tactical brief in the design phase and an operative brief for the construction phase.

User involvement is often seen as a critical activity to ensure that briefs reflect the needs, requirements and wishes of the future users of the building. Jensen and Pedersen (2009), for example, express the need for ‘inclusive briefing’ – an interactive process, where the demand and supply sides are involved in a mutual dialogue process. Prins et al. (2006) address a need for feedback to, and dialogue with, all stakeholders. Jensen et al. (2011) suggest a guided learning and dialogue process with client and user representatives that actively involve users, especially if work flows and processes change in part of an organization. Furthermore, these authors add that briefing concerns all the clients’ and user needs in developing a facility and it is a continuing process with changing focus in different phases. Jensen (2006) identified the following reasons as the most important for involving users in the briefing process:

- Ensure that new facilities are designed in accordance with the needs and intentions of the organisation.
- Learn from good and bad experiences with existing facilities.
- Ensure acceptance and appreciation of the new facilities among managers and staff.

2.3 Usability briefing

The importance of briefing has been stressed in various publications, for example by Barrett and Stanley (1999) and Blyth and Worthington (2001), Jensen and Pedersen (2009) and the REBUS project (Blakstad et al., 2010). The recent work by CIB W111 (Alexander, 2010) on usability has also highlighted the importance of briefing as means to achieve usability.

Jensen et al. (2011) notice interesting implications for the briefing process if usability is seen as a contingent quality rather than as the inherent functionality of the physical environment. They introduce the idea of ‘usability briefing’ and see a need for further research in briefing and the role of the users in the briefing process and how to manage inclusive and continuous briefing with user involvement, as well as research that evaluates the effects of user involvement for different types of users, processes and facilities.

This paper will address the suggestions made in Jensen et al. (2011). It begins with comparing the characteristics of traditional and usability briefing in Table 1, and will suggest additional relevant characteristics, i.e. concerning existing or future facilities, process being continuous in all phases with changing focus, and the importance of co-learning and co-designing.

2.4 Related concepts

In the literature, one can find a host of concepts, tools and methods that are related to briefing and usability. These range from very concrete POE's to more abstract theoretical notions such as boundary objects (Star and Griesemer, 1989). The most important ones, which are relevant to the presented process model, will be introduced below.

Table 1: Comparison of traditional briefing and usability briefing. Revised and adapted from Jensen et al. (2011) and Jensen and Pedersen (2009)

Traditional briefing	Usability briefing
Concerns new building/construction	Concerns all client/user needs in existing or future facilities
A definite phase at an initial stage of construction	A continuous process with changing focus in all the phases of building life cycle including occupancy
An expert based information collection	A co-learning and dialogue process
Users mainly involved as data sources	Users actively involved as co-designers and part of a corporate change process
The result is a brief, i.e. a requirement specification	Continuous collection of visions and requirement specs, with changing detail and focus

Evaluations, POE, Usability Appraisal

Researchers highlighted evaluation and briefing as key processes to achieve usability and effective facilities (Blakstad et al, 2010, Jensen, 2010). Various methods and tools exist for evaluating existing facilities. The focus is usually on the technical building performance, function/usability or form/beauty. Central examples of evaluation methods are: Post-Occupancy Evaluation (POE) and Usability Appraisal. The most known usability assessment methodology is *POE*. Preiser et al. (1988) and Preiser and Vischer (2005) defines POE as "the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time". Conventional methods are questionnaires, interviews, workshops, space measurement and cost analysis. See Fronczek-Munter (2013) for a full overview.

USE-tool

Blakstad et al. (2010) made a usability mapping tool, the USEtool, which is targeted to be used by building owners and facilities managers. The process has five stages. The first stage is the introductory identification stage (investigation of organisational objectives and relevant user groups), and a systematic general usability mapping and a walkthrough with more in-depth qualitative studies of specific usability topics. The last stages of the process include comparing findings with objectives, and developing recommendations for improvements in existing buildings or briefing for new facilities. This method was used in case study 3 (SOH), see section 0.

User involvement

Different approaches to user involvement and methods were shown in Sanders (2006), describing emerging trends in design research, where users can be seen as either co-creators or merely data sources, and interest is on either knowledge gathering or design. Discussions about who the users are and which users to involve were presented by Kernohan et al. (1992), Sæbøe and Blakstad (2009), Olsson et al. (2010), and Fronczek-Munter (2011).

User driven innovation, lead users

User driven innovation (Ehn and Kyng, 1987, von Hippel, 2005) is the participatory design process in which users are (co-) creators of design. Von Hippel (2005) claims that most innovating users have characteristics of lead users - they are ahead of the majority. It is an interesting approach because it is different from the standard practice in construction briefing to involve users that preferably represent all types of users, including not only 'early innovators', but also the 'late majority'.

Boundary objects

The concept of boundary objects has been described by Star and Griesemer (1989) as a concept of problem solving by means of translation; they can be abstract or concrete objects, as media of communication. Further studies include Clarke and Fujimura (1992), Vinck, et al. (1996), Kjølle and Gustafsson, (2010), Carlie (2002, 2004), Wenger (2000), Boujut and Blanco (2003), Broberg et al. (2011) and Fronczek-Munter (2011). They will be understood here as tools, objects, tasks, methods used in user involvement sessions.

3 APPROACH

The model presented in this paper is inductively developed from the literature review presented in section 2 and three case studies of hospitals in Denmark and Norway. Furthermore, it is based on RIBA's planning phases from 2013. The RIBA phasing has been chosen as the backbone for the approach as a way to connect to practice.

The development of the model has taken place by combining the mentioned theories and concepts, with the case study findings. It has been an iterative process, in which theories were compared to practice and vice versa. Ideas came from reading and from the many talks to the informants and interviewees in the case studies. The aim has been to translate the many different concepts and ideas that were found into a single, coherent model for usability briefing. The limitation of the proposed model is that it has not been tested. So, it is more like a hypothesis than a 'proven' solution. Further qualitative empirical research will have to refine and test the model.

4 RESULTS

This paragraph discusses the results of literature study and cases studies. First the case studies are introduced (section 0). Then the insights from case studies and literature are put into the newly developed process model of usability briefing. The proposed model is first described in general terms (section 0) and later in more detail, focusing on the first two phases of the overall model (section 0).

4.1 Empirical findings from hospital projects - cases

Three case studies are briefly introduced below; see Table 2 for an overview.

Case study 1 - Bispebjerg Hospital project (BH), occurred in the period 2010 - 2012, where the processes of user involvement and briefing were observed for the master plan competition at Bispebjerg Hospital. Furthermore, interviews were done with managers from the project group, and architects and workshop facilitators who were involved in briefing and user involvement processes. The Bispebjerg Hospital project consists of two parts: the New General Hospital and the New Psychiatric Hospital Bispebjerg, that are both located on Bispebjerg Hill in Copenhagen capital area. In the years 2014-2025 new buildings with 121.000 m² will

be built and existing buildings with 96.000 m² will be rebuilt. The case is described in more detail in Fronczek-Munter (2013).

Case study 2 was conducted in 2010-2012 at the Gynaecologic Department at Herlev Hospital as part of **Healthcare Innovation Lab (HIL)**, which is a public-private collaboration project testing simulation and user-driven innovation between users and companies at Hospitals in the Danish Capital Region. The case study focused on the methods and results of user involvement in design, and the different ways of involving users in planning healthcare facilities. The case study was of a participative ‘action research’ nature, with active involvement in the planning, participation and evaluation of workshops with users – medical staff, observation, filming and active participation in activities. Parallel to the HIL project, there was a simultaneous architectural competition for new facilities at Herlev Hospital. The case is described in more detail in Fronczek-Munter (2011 and 2013).

Table 2: Overview of case studies

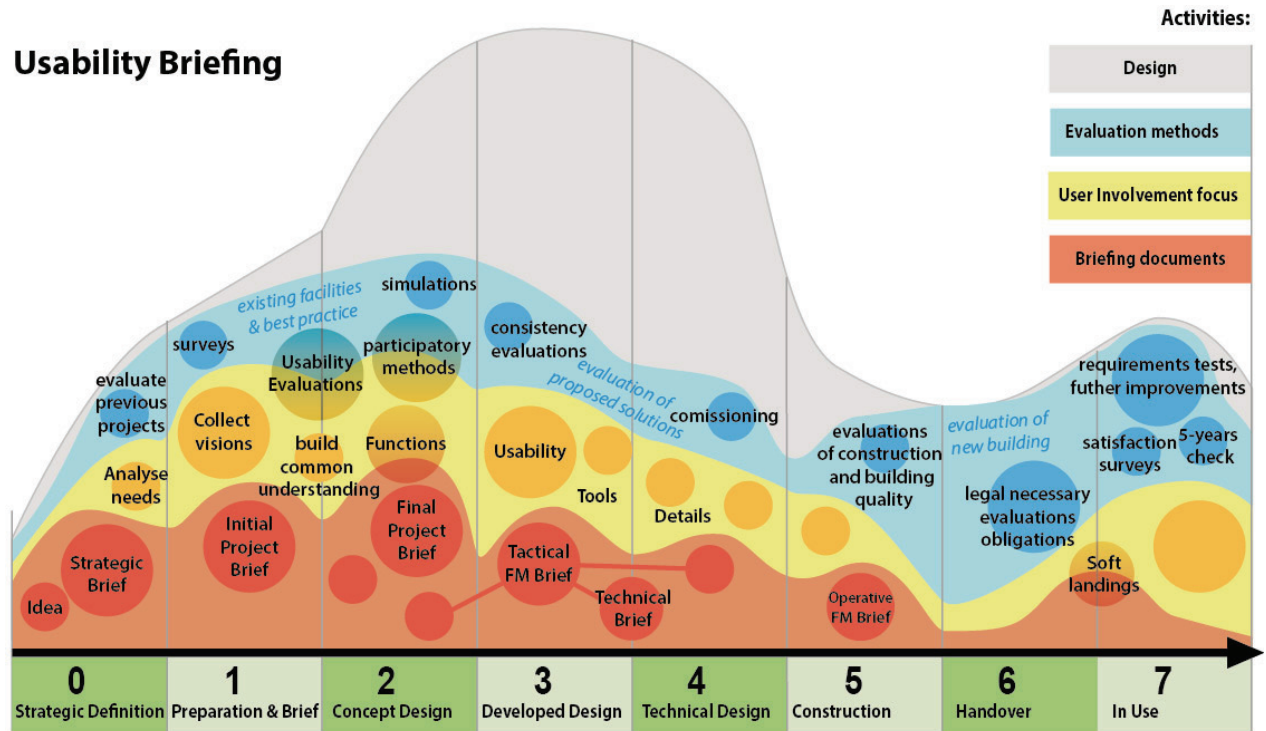
Name	Case 1, Denmark Bispebjerg Hospital (BH)	Case 2, Denmark Healthcare Innovation Lab (HIL)	Case 3, Norway Skt. Olavs Hospital (SOH)
Phases studied	0 – Strategic Definition, 1 – Preparation and Brief	1 – Preparation and Brief, 2 – Concept Design	0-6, 7 – In use
Research method	Observation of workshops with users and work meetings about briefing, interviews with managers, architects and facilitators	Planning, participation and evaluation of workshops with users (medical staff), observation, filming and active participation in activities	Phases 0-6 as historical study from literature and own interviews, Phase 7 – In use - as trial of evaluation method USEtool on one department building
Activities	User involvement, Briefing, Evaluations	User involvement, Briefing, Design, Evaluation	User involvement, Evaluations
User types	Medical staff, patients continuous user group, lead users, 6 thematic user groups	Lead users: medical staff including doctors, nurses and medical secretaries; patients – seldom Facilitators / participants: researchers, consultant companies and various specialists.	Phases 0-6: patients, relatives, patient organisations medical staff (nurses, doctors), architects – key people Phase 7: architecture students, researchers and medical staff
Tools, Boundary objects	Discussion, brainstorming presentations, document writing workshops with facilitators, graphical posters, 3d model objects, drawing, discussing, counting use of rooms during day	User driven innovation, participatory user workshops, design games, for example Ovals with poster and print, icons, Lego figures, simulations, cardboard boxes for rooms, typical patient processes, timer, drawings	0-4: Workshops – challenges and solutions, discussion, test models 5: functional site visits 7: USEtool: planning, walk through and stops, photos, observations, drawing, discussion, notes, filling out schemes, survey and interview, summary evaluation of results

Case study 3 - Skt. Olavs Hospital, Norway (SOH), was conducted partially as 1) a historical study from literature, document reviews and interviews with Chief Hospital architect and Chief medical manager, who were responsible for user involvement in 2012-2013 and 2) site visits and trial of usability evaluation method USEtool on one department building. The whole new hospital project had been divided into two successive hospital parts/phases, with several buildings in each. The case is described in more detail in Fronczek-Munter (2013).

4.2 Usability Briefing process model – general description

Based on literature studies and new knowledge gained from case studies, a model for usability briefing was developed, shown in Figure 2.

Figure 2: Usability Briefing process model. Axes not to scale.



The aim of the model is to give an easily understandable overview of the engagement over time in the different processes that can constitute usability briefing in the building design process phases. The four activities in the model are: briefing, user involvement, evaluations and design, each shown as a coloured layer. The model is based on the building design phases presented by RIBA (2013), numbered from 0 – Strategic Definition, to 7- In Use. The effort shown for the four activities are not to scale, instead the thickness of layers symbolises increasing or decreasing efforts. The coloured layers are added on top of each other, such that all activities are displayed as addition to the others in same phases.

The circles/”bubbles” exemplify main events, and can also represent focus, methods or result/documents of the activities in that phase. For example in phase 1- Preparation and Brief, the main output of all briefing activities is producing the Initial Project Brief, which is shown as a big bubble of briefing activities.

The design activity is shown as a reference only and is not described in details. The other 3 activities are the main activities that are considered as essential for a good briefing process with a focus on usability. They are shown as separate activities and layers, but they do interact with each other, i.e. in phase 1 the Evaluation surveys in evaluation layer can help with collecting visions at user workshops – user involvement layer, which in turn help developing the Initial Project brief – in the Briefing activities layer.

The novelty of the usability briefing model is combining the 4 known activities of briefing, user involvement, evaluations and design and arranging them throughout all building design

phases, relative to each other and additionally recommending the main events, focus of the stages and methods to be applied.

The premise of the model is that usability topics are explicitly being addressed in each of the 4 activities. It means that usability topics are formalized (e.g. in agendas, notes, documents), discussed (in workshops, design meetings) and systematically evaluated (e.g. in design appraisals). Furthermore, the idea is that usability topics are explicitly hold on to when switching from one activity to another, avoiding that issues get 'lost' along the way. For example, if the issue of hospital bacteria comes up in early workshop with users, this issue should then explicitly be mentioned as a concern in the early briefing documents. These should then, at a later stage, be translated into detailed, testable specifications (e.g. concerning hygiene and cleaning). And next, during the design process, these should be used to systematically test ('verify') design proposals. In a feedback sessions with the users it should be explained how the design answers to their concerns.

There is no room here to discuss the model in full detail, but the generic model is developed in Table 3 with additional variables to fit the processes and users of healthcare facilities.

4.3 Usability Briefing process model – Explanation of details in phases 0-1

Phases 0 and 1 will be described in more detail, because of rich data from case studies covering those phases. All phases are described briefly in Table 3 and will be described more thoroughly in a future paper.

Phase 0 – Strategic definition

This phase is about transforming the idea into definition of a **Strategic Brief**, start of a building project.

Briefing activities and outcomes:

The first step is inception of an idea, followed by collecting expert knowledge inside and outside of the organisation, feasibility study, decisions about budget, size and location choice. For hospital projects parts of it are often a political process. The outcome is a Strategic Brief – a document stating main objectives of the project, the first visions and inspirations, as well as rough estimates/decisions about location, needs, size and time schedule.

In the **BH case** much effort was put into collecting expert knowledge about their site and future possibilities from multiple research studies by external companies. It is important to base the important initial decisions on valuable and trustworthy data. Some of it may come from external studies and some from user involvement with internal users and evaluation activities.

User involvement:

Managers and top level users meet for a few workshops about stating the needs for the new project and estimating scope of the project. The input to strategic brief is about first visions, size and extent of project. Start of a building client organisation with connection to managers and users.

The idea is to find and select the lead users in this phase – advanced users because of position or special knowledge, as in the **BH case**. There, they quickly found lead users - medical staff at high positions i.e. department directors, who had strong visions and were discussing them together with top hospital managers and building client team. Furthermore, a continuous user group was established, a group of lead users, that meets regularly throughout the whole build-

ing process securing both management contact, advice to the building process and the continuity of solutions. In the **SOH case** the political context of "The patient in focus" defined the users to be patient and relatives' organisations, whereas medical staff was not participating in "user-", but in "employee involvement".

Generic recommendations are to choose a varied team from patient organisations and medical departments to get the big picture, common understanding and visions. Possible boundary objects and tools are: prioritising with "bull's eye" poster and discussions, feasibility studies.

Evaluation:

Suggested activities are two types of evaluations: 1) Looking at previous experiences with building projects. 2) Evaluating existing facilities and organisation, by collection of main facts about the organisation and buildings, size and needs. The tools can be brainstorming, focus group interviews, archive documents study.

The **BH case** made two types of evaluations at this stage, which can be recommended to other projects and the generic model. The first was room counting of all existing rooms and their usage over the day, to assure that space is not empty and help to estimate the proper future needs of room types and amount of space. The other was study trips to other locations in the world to get inspiration to architecture, solutions in hospital buildings, interiors, parking and logistics.

Phase 1 – Preparation and Brief

Phase focus is on creating an **Initial Project Brief** based on the Strategic Brief from phase 0 and relevant information from experts, users and evaluations in order to strengthen the visions, clarify the data about the size, extent and form of project.

Briefing activities and outcomes:

Briefing activities are strongly connected with user involvement and evaluation activities. All three processes are of high activity at this stage, with several work meetings, workshops and site visits. Outcome is an Initial Project Brief – a document capturing more information and decisions about the project, i.e. location, functional and organisational needs, size, design and time schedule.

User involvement and Evaluations:

Initial user workshops are focusing on capturing strong visions for the new facilities, such that they reflect on prioritised needs and can be accepted and followed by the whole organisation and at the same time inspire the architects in next phases to great designs.

BH case had good experiences with highly effective lead users' workshops, which gave important input to structure and content of the master plan competition brief. It is suggested here to continue cooperation with advanced users with special knowledge. In the **BH case** just six thematic user groups with different focus were invited to a short process - a series of three workshops, with ambitious goals, but restricted focus and power, so they could talk openly and efficiently collect ideas, knowing that not all of them will be satisfied in future project. In fact they got aware of the dilemmas and took them directly to the master plan competition brief, along their direct citations and a model of the whole hospital structure.

HIL was a showcase of user driven innovation with users as co-creators of new hospital architecture and organisation. Innovation occurred in both areas at once. Many design games and boundary objects were tested and some methods and physical objects were found to be

better to inspire users to innovate and be in a designing state-of-mind. Table simulations proved to be playful and highly effective.

The **SOH case** had many user workshops (1050 in both project parts/phases). In the first part/phase of the hospital project users were involved without expectation management, with the result that the staff was not satisfied with hospital of a presumable high standard.

On the other hand, **SOH** had a successful patient involvement, with 10% patients in user groups, both individuals and representatives from patient organisations. Moreover, patient input gave a lot of design solutions to improve the hospital, both for patients and staff, which would not have appeared otherwise. Other countries, like Denmark or USA unjustifiably consider patient involvement as a difficult process not producing results. It is possibly a matter of proper planning and preparation, unlike in **HIL case** project, where patients were involved, but only very short and in a different ways than other participants.

Here, it is recommended to organize workshops to enable users and designers to co-create and choose focus areas for user groups or each workshop (BH). The continuous user group (BH) can be started at stages 0-1, securing a continuous feedback and continuity of solutions. Also recommended is to 1) try different facilitation methods, design games and simulations, 2) invite more types of users and inspiring them, learning other ways of layout and working procedures at other sites and co-creating new solutions, enabling innovation (See Fronczek-Munter, 2011 for more information).

A brief overview of additional variables to the model in all phases is presented in Table 3.

Table 3: Overview of selected additional variables in the usability briefing model

Phases	Phases 0-1 <i>pre-design</i>	Phases 2-5 <i>design and construction</i>	Phases 6-7 <i>Handover and use</i>
Users	Lead users, patient organisations managers, top level users	Various users: main (patients, relatives, doctors, nurses, architects, secretaries) and secondary (facility managers, service, operational staff),	Various groups, continuous involvement
Methods tools, boundary objects	Meetings, feasibility studies, document re-views, surveys - BUS, evaluations-PDE/POE, usability assessment – USE-tool	Participatory workshops with users, co-designing, co-learning, design games, observation, evaluations of proposed solutions – simulations, AEDET, Healthcare Design Action Kit, commissioning	Soft landings – buildings operational manual and learning, satisfaction surveys, requirements tests and further improvements – WODI, DQM, POE, ST&M, ASTM standards
Focus	Visions, collect data, analyse needs, own existing facilities and best practice, common understanding, inspiration	usability, functionality, creativity, innovation, transforming visions to prioritised needs, from general to detailed and operational	Evaluations – tests and improvements, learning how to use the new facility
General results	Capturing needs and visions	Prioritising, innovation, requirement specification, inspiration for innovative design	Learning how to operate, documentations, improvements/adjustments
Results as documents:	Strategic brief, Initial project brief	Final project brief, Tactical FM brief, Operative FM brief	Documentations, survey results, benchmarking data

5 PRACTICAL IMPLICATIONS

The research results have relevance to researchers, client organisations, facility managers and architects planning new complex facilities, and especially for professionals planning hospitals.

6 CONCLUSION

This paper proposes an integrated usability briefing process model for continuous briefing, combining the four known, interrelated activities of briefing, user involvement, evaluations and design. It provides visual overview of them in all building design phases and presented additional variables to the usability briefing model in a brief table with suggested users, methods, focus, results and documents to the grouped phases. That table needs to be further detailed and incorporated in the usability briefing model with all separated phases.

The proposed model is theoretical and needs to be applied and further tested. Because of the empirical results, the explanation of the process model focuses mostly phase 1 and 2 of the RIBA planning model. The main concluding suggestions are to secure: continuous user presence throughout all phases, co-creation, design and evaluation with various users/stakeholders, using relevant and creative boundary objects at workshops.

REFERENCES

- Alexander, K. (Ed.) (2006), *Usability of Workplaces - Report on Case Studies*. CIB - International Council for Research and Innovation in Building and Construction. CIB-report 310.
- Alexander, K. (Ed.) (2008), *Usability of Workplaces – Phase 2*, CIB and Euro FM Joint Project, CIB-report 316.
- Alexander, K. (Ed.) (2010), *Usability of Workplaces – Phase 3*, CIB and Euro FM Joint Project, CIB-report 330.
- Barrett, P. and Stanley, C.A. (1999), *Better Construction Briefing*, Wiley-Blackwell.
- Blakstad, S.H., Lindahl, G., Nenonen, S. (2010), *User-oriented benchmarking for usability of real estate – The REBUS research project*, Chalmers University of Technology, Göteborg.
- Blakstad, S.H., Olsson, N., Hansen G.K., Knudsen, W. (2010), "Usability mapping tool" in *Usability of Workplaces – Report on Case Studies*. Alexander K. (Ed.), CIB-report 310.
- Blyth, A. and Worthington, J. (2001, 2013) *Managing the brief for better design*, Spon Press.
- Boujut, J.-F. and Blanco, E. (2003), "Intermediary objects as a means to foster co-operation in engineering design", *Computer Supported Cooperative Work*, 12, 205-219.
- Broberg, O., Andersen, V., Seim, R. (2011), "Participatory ergonomics in design processes: The role of boundary objects", *Applied Ergonomics*, 42 (3), 464-472.
- Carlie, P.R. (2002), "A pragmatic view of knowledge and boundaries: boundary objects in new project development", *Organization Science*, 13, 442-455.
- Carlie, P.R. (2004), "Transferring, translating, and transforming: an integrative framework for managing knowledge across boundaries", *Organization Science*, 15, 555-568.
- Clarke, A.E. and Fujimura, J.H. (1992), *The right tools for the job: At work in Twentieth-century life sciences*, Princeton University Press.
- DANSKE ARK / FRI (2012), *Ydelsesbeskrivelse Byggeri og Planlægning*, published by DANSKE ARK and Foreningen af Rådgivende Ingeniører.

- Ehn, P., and Kyng, M. (1987). *The collective resource approach to systems design*. In Bjercknes, G., Ehn, P., and Kyng, M. (Eds.), *Computers and democracy: A Scandinavian challenge*, 17-57. Aldershot, UK: Avebury; Brookfield, VT: Gower.
- Fristedt, S. and Ryd, N. (2004): *Att lyckas med program – Kontinuerligt programarbete för bättre styrning av byggnadsprojekt (To succeed with brief – continuous briefing for better building project management)*. Arkus, Stockholm.
- Fronczek-Munter, A. (2011), "Facilitating user driven innovation - a study of methods and tools at Herlev Hospital, conference paper in Nordic Facilities Management Conference 22-23 August 2011. Research for Practice - Vision of Futures, Conference Proceedings
- Fronczek-Munter, A. (2011), "Usability and User driven innovation – unity or clash?", paper presented at 13th International FM & REM Congress, January 19-21 2011, Kufstein, available at: *Conference Transcript FM & REM Congress 2011*, p.218-229, <http://www.fh-kufstein.ac.at/fmg/Fmg/Downloads>, (accessed: August 01 2011)
- Fronczek-Munter, A. (2013), Evaluation methods for hospital facilities, EuroFM Journal International Journal of Facilities Management, Proceedings of conference papers from the 12th EuroFM Research Symposium, Prague, Czech Republic 22-24 May 2013. P. 215-226
- Fronczek-Munter, A. (2013), User involvement and briefing for masterplan competition at Bispebjerg Hospital (Brugerinvolvering og programmering for masterplan konkurrence på Bispebjerg Hospital), special edition of the professional journal FM Update, CFM Articles 2009-2013. P. 101-106.
- ISO (1998), "Usability", ISO 9241-11, International Organization for Standardization.
- Jensen, P.A. (2006), "Continuous briefing and user participation in building projects" *Adaptables 2006: Proceedings of the joint CIB, Tensinet, IASS International Conference on Adaptability in Design and Construction*. Vol. volume 3 1. ed. Eindhoven, The Netherlands : Eindhoven University of Technology, p. 119-123.
- Jensen, P.A. (2010), "Management for usability of learning buildings", Alexander (Ed.) (2010)
- Jensen, P.A., Alexander, K. and Fronczek-Munter, A. (2011), "Towards an agenda for user oriented research in the built environment", paper presented at 6th Nordic Conference on Construction Economics and Organisation, 13-15 April 2011, Copenhagen, in Haugbølle, K. et.al (Ed.), *Shaping the Construction/Society Nexus, Volume 1: Clients and Users*, 25-42, available at: <http://vbn.aau.dk/en/publications/proceedings-of-the-6th-nordic-conference-on-construction-economics-and-organisation--shaping-the-constructionsociety-nexus%28dc83b456-0710-42e7-a828-706e356c21eb%29.html>, (accessed: August 01 2011).
- Jensen, P.A. and Petersen, E.F. (2009), "User involvement and the role of briefing", in Emmitt, S., Prins, M., den Otter, A. (Eds.), *Architectural Management – International Research & Practice*, Wiley-Blackwell.
- Kernohan, D., Gray, J., Daish, J. and Joiner, D. (1992), *User participation in building design and management*, Butterworth-Heinemann, UK.
- Kjølle, K.H. and Gustafsson, C. (2010), "Boundary objects in design", Atkin, B., Borgbrant, J. (Eds.), *Performance Improvement in Construction Management*, Spon Press, London and New York.
- Nutt, B.: (1993): *The Strategic Brief*. Facilities, Vol. 11, No. 9, 28-32.
- Olsson, N.O.E., Blakstad, S.H. and Hansen, G.K. (2010), "Who is the user" in *Proceedings CIB W70 Conference*, Sao Paolo.
- Preiser W. F. E., Rabinowitz H Z and White E T (1988): *"Post Occupancy Evaluation"*, New York: Van Nostrand Reinhold.
- Preiser, W. F. E. and Vischer, J. (Ed.) (2005): *"Assessing Building Performance"*, Elsevier

- Prins M., Koolwijk J., Volker, L. and Wamelink J.M.F. (2006): *Briefing: Static or Dynamic?* In: Proceedings of the joint CIB, Tensinet, IASS International Conference on Adaptability in Design and Construction. Eindhoven University of Technology, Netherlands.
- RIBA (2013), Plan of Work, Royal Institute of British Architects, website: <http://www.ribaplanofwork.com/>, accessed: 29.11.2013
- Sanders, E.B.-N. (2006): *Design Research in 2006. Design Research Quarterly*, V.1.1. September 2006. Design Research Society.
- Star, S.L. and Griesemer J.R. (1989) "Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's museum of vertebrate zoology, *Social Studies of Science*, 19, 387-420.
- Sæbøe, O.E. and Blakstad, S.H. (2009): *Fasilitetsstyring. Verdiskaping – Verdiøkning - Verdibevaring (Facilities Management – Value Creation – Value Adding – Value Sustaining)*. Temahefte 2: Eiendomsutvikling og forvaltning. Tapir forlag. Trondheim
- Vinck, D., Jeantet, A. and Laureillard, P. (1996), "Objects and other intermediaries in the sociotechnical process of product design: an explanatory approach", Perrin, J., Vinck, D. (Eds.), *The Role of Design in the Shaping of Technology*, European Commission Directorate-General Science. Research and Development, Brussels, pp. 297-320.
- Van der Voordt, T.J.M. and van Wegen, H.B.R. (2005): *Architecture in Use – An introduction to the programming, design and evaluation of buildings*. Architectural Press, Elsevier, Oxford.
- Vitruvius, translated by Morgan, M. H. (1914), "The ten books on architecture", Cambridge, Harvard University Press, London: Humphrey Milford, Oxford University Press, (2006) - The Project Gutenberg EBook
- von Hippel, E. (2005), *Democratizing Innovation*, MIT Press.
- Wenger, E. (2000), "Communities of practice and social learning systems", *Organization*, 7, 225-246.

7.4

PEOPLE FLOW AND EXPERIENCED SAFETY – USE-CENTRIC METHOD TO IMPROVE THE PRODUCT

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ABSTRACT

Purpose: The goal of this paper is to present how users of high rise office buildings perceive safety as part of their journey in and between the buildings. This research is used to improve the people flow experience. This paper is joint effort with academic research and service development of a service provider company.

Background: Service provider Kone defines People Flow TM experience as “enabling people to move smoothly, safely, comfortably, and without waiting in and between buildings”. The experience design requires continuous gathering of user data.

Approach: Theoretically our paper builds on the environmental psychology in the context of perceived safety as well as discussion of customer value proposition, which is based on economic (price), functional (solutions), emotional (customer experience) and symbolic value (meanings). The data is gathered by using service design methods: user journey and probe including self reported diaries with pictures. The data is gathered from 3 high rise office buildings and number of users is 20.

Results: The safety experience elements were: tidiness the presence or absence of other people, having clear boundaries between ‘our’ space and that of others and visibility and space around was found to increase the feeling of safety. Finally, the absence of obstacles was found important.

Practical implications: The results are used for experience design: focus is especially on advancing people’s sense of safety and security based on their experiences within People Flow TM design and development.

Research limitations: As the data was qualitative in nature and consisted of a limited data set collected in a particular cultural setting of Finland, it is not generalizable to all contexts.

Originality: User-orientated approach provides unique ground for testing service design methods in the research of usability of built environment in terms of people flow.

Keywords: Experience, Elevators, Public space, User experience, Environmental psychology

1 INTRODUCTION

Experiences, like goods and services, have their own distinct qualities and characteristics and present their own design challenges (Pine and Gilmore 1998). In order to develop the people flow experience the chain of different stakeholders need to take benefit out of the user experience investigations. The chain includes: the elevator company (its designers, directors and manufacturers), the purchase decision-makers (propriety managers, owners, boards etc.) and their interests (low-cost, income generation, customer appeal in property) as well as tenants – business owners, organisations and their interests. In the center are the users e.g. staff and customers and their interests (e.g. safety, time-efficiency, comfort, reduction of negative emotions). (Rousi and Saariluoma 2011) The concept of customer satisfaction is outcome-oriented focusing mainly on functionality of the service/product. Experience in contrast, is process-oriented including all the moment of contacts and emotions during the experience (Schmitt 1999). Norman (2002; 2004) describes how product developers need to consider how potential users think and feel. In order to shift from providing solutions and functions one need to count on more intangible emotional and symbolic aspects.

The goal of this paper is to present how users of high rise office buildings perceive safety as part of their journey in and between the buildings. This research is used to improve the People Flow TM experience. This paper is joint effort with academic research and service development of a service provider company.

The paper focus on people flow and perceived safety in Chapter 2. After research design in Chapter 3 the results are presented and summarised. The paper is concluded with practical implications and conclusions.

2 PEOPLE FLOW AND PERCEIVED SAFETY

2.1 People flow, safety and security - concepts

People flow as a concept relates to the phenomenon of masses of people moving around in buildings in an organized, comfortable and safe way. It is important to understand user needs in order to enable people to move smoothly, safely, comfortably and without waiting from one place to another. The journey of people flow includes also the entrance area of the building and the public space outside the building.

The concepts safety and security have many definitions, depending on the viewpoint. Security can be defined as relating to protection against intentional damage while safety relates to protection against unintentional, accidental or environmental damages (Kupi et al 2010). The feeling of safety or security is related to many aspects in addition to fear of crimes (Suominen 2009).

2.2 Perceived safety

A study by Nørgaard and Børresen (2008) indicates that the experience of being unsafe often is related to perceptions rather than actual experiences. In addition, the sense of safety or security is very individual, and personality, background and personal experience all strongly affect our experienced safety or security. Individuals of different age/ sex/ background have a different view on what seems unsafe and what does not.

In larger scale urban planning and the development of different communities have a strong effect on both the areas safety and security, and real and experienced safety are important parts of the emerging and development of a sense of community. The constructs of residential areas as well as the residents' cooperation strongly affect the residents' sense of security. Experienced or perceived safety is therefore an important part of the individual's quality of life). The design of an area can in some cases itself influence the growth of a regional sense of community. Another way of enhancing a certain neighbourhood's security is through gates and fences. This is commonly used for example in the USA. However, building barriers such as gates may have negative effects as well, such as reinforce the feeling of fear of the area outside the barriers. (Saville and Cleveland, 1998)

Environmental psychology research has put lot of attention to security and safety perceptions. Voordt and van Wegen (1990) have investigated public security and e.g. Shehata (2012) has focused on the attractiveness and security perceptions in urban parking spaces. According to her findings e.g. flowers and trees may increase both perceptions of attractiveness and security, if the overall look of vegetation is well-maintained and attractively landscaped. The extent of agreement on the importance of good maintenance had also reached the architectural buildings and landscape paths, clean pedestrian walkways and good architectural style would enhance the sense of security and attractiveness. In more general conclusion is presented by Kytä et al. (2013): More comprehensive safety strategies are most likely to succeed in breaking the negative development of fear and a spiral of neighborhood decay especially in retrofit neighborhoods.

Examples of different kinds of real and experienced types of safety and security can be seen in the Table 1 below.

Table 1: Experience safety in

Safety and Security	Examples
Traffic/ road safety	Access as a part of people flow experience
Crime-related security	Safety in environment, surroundings, neighborhood
Prevention of injuries	Maintenance (such as gritting), lighting, shrubs
E-Safety	E-Identity, information security
Building-related safety	Fire safety, constructional safety, evacuation routes, materials, doors, visibility

2.3 Perceived safety and elevators

People flow in the context of elevator usage is seen as smooth flow of movement and thought of factors other than the elevator itself – elevator is one hotspot in the user journey. The efficient elevator design and operation should allow the user to continue uninterrupted in actions and interactions that are established before the user's elevator usage transaction is commenced (Rousi 2013). Vischer (2006) has investigated the macro environment of an organization: there are many approaches to assessing the degree to which workspace helps (or fails to help) a company meet its business objectives and/or increase its competitive advantage.

Organisational effectiveness is affected by locational advantages and ease of access, balancing consolidation under one roof (centralisation) with dispersion of different groups in different facilities over manageable distances, and by building amenities such as fast elevators, convenient bathrooms, adequate parking, and attractive eating areas. In terms of living e.g. Gifford (2007) has identified some fears as well as pleasantness connected to vertical transportation in high rise buildings in housing.

Rousi and Saariluoma (2011) have investigated user experiences in elevators. Based on interviews they pointed out that 25% of the 44 interviewees were concerned about the length of waiting times and duration of the elevator travel. A one-hour observation of 62 people showed that 50% of the elevator users stepped into an elevator in less than a second of pressing the hall call button. Twenty-six per cent stepped in between two to five seconds, 10% six to ten seconds, 6% 11 to 15 seconds and 8% over fifteen seconds. In other words, it was seen that people's perceptions of waiting duration might be longer than they actually are.

According to Rousi and Saariluoma (2011) interviewees responded to the categories of aesthetic features such as colours, music and sound, a key discursive theme was safety and security in elevators. Experience of the elevator sounds contributed to a sense of (or lack thereof) security and safety. It was important that users were not too aware of the heights and mechanics of the elevators. Sounds such as wind in the elevator shafts and irregular operational noise caused anxiety.

Further, positions of hierarchy and gender order were observed in the way people positioned themselves in the cabs. For example, generally men stood at the back and women stood at the front. Men would interact with design features such as mirrors and women would not unless there were only a few other women elevator users present. Some were consciously aware of these dynamics and stated in the interviews that sometimes for fun they would either stare at other users or face the 'wrong' direction (i.e. towards the back of the cabin rather than the doors) (Rousi and Saariluoma, 2011).

2.4 Developing people flow experiences and perceived safety

Rintamäki et al (2007) have investigated customer value and competitive advantage in order to form an understanding of the key dimensions of customer value, developing a hierarchical model of value propositions and establishing a link between customer value and competitive advantage. They identified four competitive customer value propositions (CVPs) where four hierarchical key dimensions of customer value: Economic value (price), functional value (solutions), emotional value (customer experience) and symbolic value (meanings). Such values have different importance for different stakeholders. The interest from economic and functional value can gain from understanding the emotional and symbolic value of the product. The former are more tangible ones while the latter two are connected to the feelings and experiences.

Jordan (2000) takes an organised approach to explaining the hierarchy of user needs, whereby functionality and usability should be incorporated with differing elements of pleasure which include: physio, psycho, socio and ideopleasure. Safety is seen to be one of the basic needs for any individual (e.g. Maslow, 1943).

One can also approach also the positive and negative experiences. E.g. in sequential incident technique draws from critical incident technique (CIT) in which the customer is asked to de-

scribe those moments in service process that were in some respect exceptional – either in good or in bad. Then the data is classified into different types of experiences with content analysis. (Bitner et al. 1990) Based on Kuniavsky's (2003) observations on positive and negative valence in experiences the positive experiences do not always lead to the success of a product, but negative experiences always lead to failure.

Assessing the customer experience during user path from the perspective of people flow can be made by interviews or surveys. After the entire data has been collected, it may be then analyzed. If they survey is conducted, then statistical methods are applicable. If the customer experience is studied by interviews more qualitative methods are applicable (Stauss and Weinlich, 1995).

Buchenau and Suri (2000) have identified that experience prototyping and also the subjective simulations in real situation have contributed to real design projects e.g. by helping to develop understanding about the essence or essential factors of an existing experience. They have e.g. used a train journey where the design team explored different types of travelers, their needs, and various unexpected situations during specific stages of a train journey (e.g. entering the station, ticketing, waiting, riding the train, connecting to other means of transportation). Each stage and step was like a scene, which put the different physical objects to serve as a platform for the experiences during the user journey. As a methodology user journey provides holistic and systematic perspective how people perceive each touch point and how they would like the user experience to be. This method can be applied also when the usability of the built environment is investigated (Rothe and Nenonen, 2007; Rasila and Nenonen, 2009).

3 RESEARCH DESIGN AND METHODS

This study focuses on a high rise office buildings and experienced safety/ security. Taking the users of the elevators into consideration when studying safety and security is important for understanding the experience. The actor base in this case is at the moment quite homogeneous, but is planned to become more heterogeneous. The data is gathered by using service design methods: probes, which included self reported diaries with pictures and which were organised based on user journey from arrival to exit from the building. Design probes are an approach of user-centred design for understanding human phenomena and exploring design opportunities. The probes emphasise the user's active role in recording the material, and one can identify similarities with the characteristics of applied ethnography from the results. (Mattelmäki, 2006.)

The data are gathered from three high rise office buildings and number of users is 20. The users of the buildings participating in the study worked in these office buildings and thus visited them regularly.

The method of data collection was story cards. The users focused on experiences of safety and security in the context of inside and close proximity to office buildings. The users took pictures and filled the design probe with story cards. The story cards were organised according to user journey with seven steps from approaching the area and building to exiting from the building and area. In each step the user was asked to take pictures, explain them and identify the general and specific elements of experience of safety as well as to nominate top three factors effecting to the experience. Additionally the background information about the respondents was included.

The data was analysed with content analysis of pictures and text. Based on the research questions, analysis focused on how participants both visually and verbally portrayed their feelings of safety and security or unsafety. We looked at the places, artefacts and people that users had included in their pictures and texts. Analysis was conducted iteratively within pictures, between pictures of a particular user and on the level of the whole data set. Analyses of the textual and visual data were conducted separately and then brought back together.

4 RESULTS

There were four independent themes that respondents valued when moving around and between buildings. Even though these themes are independent, they are nevertheless closely related to each other. The first two themes focus on environmental characteristics and the latter two on the presence and absence of other people.

As photographic data were relevant to our analysis, we have included examples of each of the themes into the discussion of findings. Of each theme there are two contrasting pictures: one of a situation that was found to be safe and another one from a situation that was regarded as unsafe.

The first two themes presented next are related to the environment and the final two themes are related to the people encountered (or not) in this environment.

4.1 Expected or unexpected

Users participating in this study respected stability and encountering the expected rather than change and encountering the unexpected. As they were moving around in places that they new well, they might have been doing in a routinized way, which was distracted by unexpected changes in the environment. Feeling of security was thus built on knowing one's surroundings.

Change in the environment was most often found to be negative: something had broken or something seemed not to be taken care of. Litter and general unkempt look of an area could also contribute to this feeling. A general expected cleanliness was considered as safe, as it was often what was expected. In our analysis then, stability is linked to cleanliness and well-kempt surroundings, and change is related to a change towards worse, something has been broken or not yet taken care of.

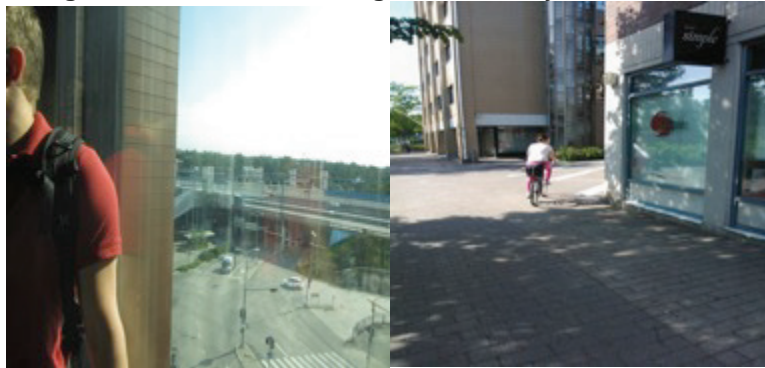
Picture 1: Left: taken care of, safe – right: not taken care, not used, dangerous



4.2. Visibility or obstacles

Visibility, light and space were also important to people's sense of safety and security. Within our data, there were plenty of pictures looking into the clear horizon that were found safe and horizontal views with a block that were found unsafe. There were many pictures of a road or a corridor leading into nothing or leading into a block at the end of way. So unobstructed views of one's surroundings were important not only outdoors, but also within the buildings and within the elevators. Also light was found important. An elevator with a big window letting in a lot of natural light was found safe. It also gives one a big view on the surroundings. On the other hand, a corner without clear view of what is to come makes the situation feel unsafe.

Picture 2: Left: Light and horizon, safe – right: invisibility behind the corner, unsafe



4.3. Solitude or company

The third theme focuses on the people found in the surroundings. The theme of solitude and company is also closely related to that of stability and change. In this case, the change is not happening in the environmental characteristics, but in the people inhabiting a certain space. People are expecting other people and when they are not there it may cause feelings of unsafety. Also in some places they may expect not to find people and when they are they are regarded as threatening. Therefore based on a person's previous experiences, people within known surroundings can be regarded as either increasing or decreasing one's feelings of safety and security.

In the first picture there are people outside the doors that increase the person's feeling of safety. In the second picture, the person she is expecting to be there is not, and thus her feeling of safety is decreased.

Picture 3: Left: people outside, safe – right: no one in reception, unexpected, unsafe



4.4. Us and them

This final theme is related to people as well, and technology that enables this distinction. People feel safe when they can block strangers out of their office; visitors are not able to access without someone accompanying them. This builds feelings of home, safety and security through knowing one's surroundings and people within those surroundings. These can be both in elevators and in office doors. This same distinction is made in the outdoors; people hoped for clear markings between the space reserved for people using different forms of transportation.

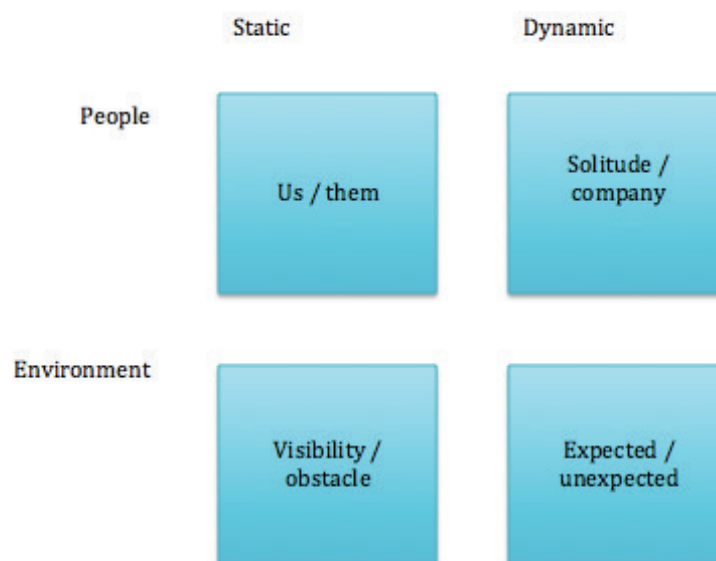
Picture 4: Left: Limited access with key card: safe – Right: Cars overwhelm from parking slots to pavements: unsafe



4.5. Summary of the results

These four themes of 1) expected / unexpected 2) visibility / obstacle 3) solitude / company 4) us / them can be placed on a following matrix. On the vertical axis there are experiences connected to people or environment. The horizontal axis indicates dimension between static and dynamic situations.

Figure 1: Matrix of safety experiences



The four different types of groups of experienced safety can be identified:

1. In the static situation the presence of non-presence of the people can effect to the experience of safety. The experience of us, belonging to the group of other people or presence of other people who feel in one or another way familiar increases the safety. The feeling of “them” can increase the unsafe. This experience is very much based on routines and the expected social behavior with connectivity or un-connectivity.
2. In the dynamic situation the balance among people are experienced as solitude and or company. One can feel unsafe and loneliness or safety and being in the company. This cluster of safety experience differs from the former cluster in terms of situation. These experiences are based on changing situations, where unexpected social grouping takes place.
3. In the static nature of environment, the experiences are connected to the feeling of controlling the environment. The increased safety is linked with visibility in the environment and decreased safety to obstacles in the environment.
4. The dynamic nature of environment includes situations, which are expected and safe and unexpected and unsafe. In comparison with the cluster two the unexpected situations are connected with unexceptional elements of built environment: the door is too heavy to open, there are problems in user-interfaces in the elevator, the information or guidance in marginal situation is lacking or is not understandable, to mention few examples.

5 PRACTICAL IMPLICATIONS

The intention of the study was to increase the knowledge how to develop more safe people flow experience. The functional qualities of the elevator should be developed in order to increase the emotional and symbolic value for the customer. The results propose that the important attributes are linked with possibility to control the environment in socially safe context.

However even more important findings are connected to the holistic perspective of people flow experience. Even the elevator is important part of the user journey; the full experience is linked with the user journey steps taken before entering to the elevator itself. As an example when the tidy environments seems to be important for the experience of safety, it is important to keep that as a rule along the user journey to the building and elevator and align the environment with the respect of this experience. Additionally the holistic approach concerns not only the development of product but also the lifecycle of the product: in terms of achieving the experience one need to be interested also the maintaining the product as a part of the built infrastructure. The product in use is even more important than product in design as a platform for usable built environment

The user information and feedback need to be gathered in the larger context. Additionally it is important to analyse more thorough way the findings from different steps. What kind of phenomena there are before the journey in the elevator, in the elevator and after leaving the elevator.

6 CONCLUSION

When reflecting the identified safety experience clusters, one can adapt the findings to the emotional values, which are important in designing the experience. Some of the findings contribute to functional elements of the product. However the important finding is also that the emotional and symbolic values are much more connected to the holistic experience of user journey. The dominant elements are also connected either to the environment or its people. Additionally the context in terms of stable or dynamic situation matters.

This research indicated what features caused users to develop affective, or emotional, relationships with different interfaces along their user journey to and away from the area of the specific high-rise buildings. The elevator is at its best the enabler for positive safety experiences either by completing or increasing the former or following steps along the journey. The chosen methods provided relevant data and increased the holistic understanding. The future research will focus on more thorough analysis of different steps. With such a small sample the different user profiles cannot be identified, but based on the qualitative analysis one can identify important themes and clusters, which can be the critical topics to be investigated also by using quantitative approach. Also the limitations of cultural context need to be taken into account.

REFERENCES

- Buchenaus, M. and Suri, J. F. (2000), Experience prototyping. In *Proceedings of Designing interactive Systems* (DIS 2000), pp. 424-433.
- Gifford, R. (2007), The consequences of living in high-rise buildings. *Architectural Science Review*, 50(1), pp.2-17.
- Jordan, P. (2000), *Designing pleasurable products. An introduction to the new human factors*. London, New York: Taylor & Francis.
- Kuniavsky, M. (2003), *Observing the user experience, a practitioner's guide to user research*. Burlington, MA: Morgan Kauffman.
- Kupi, E., Murtonen, M., Palomäki, K., Wuoristo, T. and Multanen, A. (2010), *Turvallisuusalan tulevaisuus – Raportti tulevaisuustyöpajoista*. VTT Working Papers. Espoo: VTT.
- Kyttä, M., Kuoppa, J., Hirvonen, J., Ahmadi, E. and Tzoulas, T. (2012), Perceived safety of the retrofit neighborhood: A location-based approach. *URBAN DESIGN International* 19, pp. 103 -104.
- Mattelmäki, T. (2006), *Design probes*. Helsinki: University of Art and Design Helsinki.
- Norman, D. A. (2002), *The design of everyday things*. New York: Basic Books.
- Norman, D. A. (2004), *Emotional design: Why we love (or hate) everyday things*. New York: Basic Books.
- Nørgaard, H. and Børresen, S. K. (2008). *Urban space for everyone: Challenges, conflicts and measures*. Copenhagen: Danish Crime Prevention Council.
- Pine, B.J. and Gilmore, J.H. (1998), Welcome to the experience economy. *Harvard Business Review*, 74 (4), pp. 97-105.
- Rasila H. and Nenonen S. (2009), Workplace experience – a journey through a business park, *Facilities*, Vol. 27 Iss: 13/14, pp.486 – 496.
- Rintamäki, T., Kuusela, H. and Mitronen, L. (2007), Identifying competitive customer value propositions in retailing, *Managing Service Quality*, Vol. 17 Iss: 6, pp.621 – 634.

- Rothe P. and Nenonen S. (2007), *Usability of Business Parks*. Helsinki University of Technology.
- Rousi, R. & Saariluoma, P. (2011), Investigating mental contents of elevator design user experience through ethnographic inquiry. Presented at the 18th international product development management conference - innovate through design, *ELASM*, June 5th-7th, 2011, Delft, Netherlands.
- Rousi, R. (2013), The experience of no experience – Elevator UX and the role of unconscious experience. In A. Lugmayr (Ed.), *Proceedings of Academic MindTrek 2013*, Tampere: ACM.
- Saville, G. and Cleveland, G. (1998), 2nd generation CPTED: An Antidote to the Social Y2K Virus of Urban Design. Paper presented at the 3rd *Annual International CPTED Conference*, Washington, DC, December. (Accessed 13.10.2013 www.e-doca.net)
- Schmitt, B. (1999), Experiential Marketing. *Journal of Marketing Management*, 15(13), pp. 53–67.
- Shehata, W. (2012), Perceived Attractiveness and Security of Design Features in Urban Parking Lots. Case study: Stationsplein, Enschede, the Netherlands. In *Proceedings of 2nd International Conference Quality of Life –a Vision Towards Better Future MTI University, Cairo, Egypt*, pp.59-80.
- Stauss, B. and Weinlich, B. (1995), *Process-oriented measurement of service quality by applying the sequential incident method*. Tilburg, The Netherlands.
- Suominen, P. (2009), *Turvallinen Suomi 2009: tutkimus suomalaisten turvallisuuskäsityksistä*. Helsinki: Sisäasiainministeriö. Poliisiosasto. Poliisin ylijohdon julkaisusarja; 7/2009.
- Vischer, J.C. (2006), The concept of workplace performance and its value to managers. *California Management Review*, 49(2), pp. 62-79.
- Voordt, D.J.M. van der, en H.B.R. van Wegen (1990), Testing building plans on public security: usefulness of the Delft checklist. *Netherlands Journal of Housing and Environmental Research* (5) 2, pp.129-154.

CHAPTER 8

SUSTAINABILITY AND CLIMATE CHANGE

8.1

An Essay on the Notion of Sustainability: Opportunities and Dangers

Paul Dettwiler

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International Trends for Sustainability in FM: Evaluation of Policy and FM Competence in Norway and UK

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8.1

AN ESSAY ON THE NOTION OF SUSTAINABILITY: OPPORTUNITIES AND DANGERS

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ABSTRACT

Purpose: The purpose of this essay is to investigate whether the concepts of “sustainability” and “sustainable development”, could be operationalised more appropriately in the future.

Background: In construction sector the treated terms have an important role and are used in multiple ways among governments, academia and various stakeholders from industry.

Approach: Through examples from society it is deduced that what is regarded as sustainable indeed demonstrate adverse effects of sustainability. It is argued that change management combined with service management (analysis through goods and services dimensions) can play a significant role to achieve a more unbiased use of the term Sustainability; because “time” is a common denominator of sustainability and sustainable development.

Results: Conclusive remarks are (1) Changes targeting sustainability should be subject to alternative calculus including consequences from broad categories, and (2) Sustainability as an absolute state cannot be attained by human activity and therefore should favourably be regarded as variable instead as a factor.

Practical Implications: Proposes a strategy for identifying secondary (tertiary etc.) effects of sustainability decisions through analysis of “goods” and “activities” and interrelations.

Originality/value: A theoretical paper (essay); it puts to question the ubiquitous use of the concepts “Sustainability” and “Sustainable Development” where dangers as well as opportunities are discussed.

Keywords: Sustainability, Sustainable development, Change, Decision analysis, Goods and Services

1 INTRODUCTION

During the conference “Sustainable Space Summit” 2013, at University of Liechtenstein, sustainability from various perspectives, related to construction sector, was presented and discussed. It became clear that “sustainability” was addressed to very different perspectives within the disciplines of environment, sociology, finance and more. Vivid discussions among the participants demonstrated that “sustainability” is indeed used in most different contexts and with different meanings and goals. During the event, opposite viewpoints and lack of consensus became evident; particularly between the proponents of “financial sustainability” against the proponents of “environmental sustainability”.

Today, most governments have the two concepts “sustainability” and “sustainable development” on their agenda for present and future planning; in particular they aim to gain control over the CO₂ emissions, pollution and the extraction of natural resources. The construction sector plays a significant role giving a long term impact on the environment and with the very different interpretations of sustainability. Since the two concepts “sustainability” and “sustainable development” are regarded as something utmost necessary for the future with a ubiquitously positive perception, neither non-commercial, commercial nor governmental organisations seldom dare to admit that any of their own planned actions would be “non-sustainable”, even if it objectively should be a true statement. Frequently, organisations regard the two concepts as unavoidable in their policies, which are indeed loaded with positive image values as preconditions for a better future.

According to Merriam-Webster (online) The adjective of Sustainability is “Sustainable” and defined as: “1: capable of being sustained, 2 a: of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged (sustainable techniques), b: of or relating to a lifestyle involving the use of sustainable methods (sustainable society). “

“Sustainable development” includes as well to economical perspective; Encyclopaedia Britannica (online): “Sustainable development is an approach to economic planning that attempts to foster economic growth while preserving the quality of the environment for future generations. Despite its enormous popularity in the last two decades of the 20th century, the concept of sustainable development proved difficult to apply in many cases, primarily because the results of long-term sustainability analyses depend on the particular resources focused upon. ...”

The various stakeholders that uncritically attributing themselves of applying sustainable policies in their planning might contrarily cause self-denial of true dangers that might occur, and in fact also hinder optimisation of measures for the society. It is therefore appropriate to pursue a basic analysis of the two concepts of their meaning and purpose, as it is the *raison d'être* of this essay.

2. SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

Hans Carl von Carlowitz described a first idea of Sustainability (German: Nachhaltigkeit), (even if it has been a practical idea of common sense since the stone age, i.e planning for the future, saving harvest seed for successive years etc.). In 1713, probably the first book (actually two volumes) on sustainability, *Sylvicultura Oeconomica*, was published in Germany (1713, von Carlowitz). The focus was a comprehensive study how the forests should function

as supply as fuel for iron production of the mining industry in a long time perspective and in the same time avoiding permanent deforestation, timber was largely used for construction and for heating in the society. In our time, after three centuries, Professor Hamberger at TUM in Munich published a new and more easily readable edition of the legacy of von Carlowitz also adding own comments (2013, von Carlowitz, Ed, Hamberger). von Carlowitz had focus on the supply and regrowth of forests, proposing alternative fuel, namely, peat instead of timber. The books also contain writings of the global observation of forests and the recommendations of von Carlowitz seem have high relevance even today. The word “Sustainability” (Nachhaltigkeit) is used only once in the book of von Carlowitz, however according to Hamberger the vocabulary is very nuanced in words like: “caring”, “continuation” and “perpetuity” (von Carlowitz, 2013).

In the 19th century, the physics of gases in the atmosphere were subject to scientific studies; the thermodynamics of the globe was described by Fourier (1827) with minor comments of human influence on the climate. Tyndal (1865) and Arrhenius (1896) gave the first step on the research of the Greenhouse effect of carbon dioxide emission in the atmosphere.

After the Second World War, the pollution due to industrial activities increased and sustainability concerns gained a global interest and recognition as a major problem issue, hastened by pollution scandals like the effects of DDT in the 1960s. The energy crisis 1973 gave a global understanding how dependent the modern civilisation is on limited energy resources. Pollution and energy issues resulted to a succession of global summits, reports and agreements, which since 40 years, are organised by the United Nations (UN). Some important milestones of UN reports are as follows:

(i), 1972, Stockholm Conference: The word “Sustainability” cannot be found in the related documents, some examples of the vocabulary are instead: (a) “Human environment”, (b) “Planning and Management of Human Settlements for Environmental Quality”, (c) “Educational, Informational, Social and Cultural Aspects of Environmental Issues” (United Nations, 1972).

(ii), 1987, The so-called “Brundtland-report”, “Report of the World Commission on Environment and Development: Our Common Future”. It contains a significant definition: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” “Part I. Common Concerns: (a) Towards Sustainable Development, (b) The Role of the International Economy, (c) Population and Human Resources, (d) Food Security: Sustaining the Potential, (e) Species and Ecosystems: Resources for Development (f) Energy: Choices for Environment and Development (g) Industry: Producing More With Less (h) The Urban Challenge, (i) Managing The Commons (j) Peace, Security, Development, and the Environment, and finally (k) Towards Common Action: Proposals For Institutional and Legal Change, (WCED, 1987).

Some more relevant citations from the Brundtland-report are as follows: “51. No single blueprint of sustainability will be found, as economic and social systems and ecological conditions differ widely among countries. Each nation will have to work out its own concrete policy implications. Yet irrespective of these differences, sustainable development should be seen as a global objective”.(p. 34), and, “72. The common theme throughout this strategy for sustainable development is the need to integrate economic and ecological considerations in decision making...”(p. 48), (WCED, 1987).

(iii), 1992, “Agenda 21” Rio de Janeiro Conference: Here Sustainability is used, titles of the sections of Agenda 21: (a) “Social and Economic Dimensions” (e.g.: “Combating poverty”, “Changing consumption patterns”) , (b) “Conservation and Management of Resources for Development” (e.g.: “Protection of the atmosphere“, “Conservation of biological diversity”), (c) “Strengthening the Role of Major Groups” (e.g.: “Strengthening the role of :” (a) “workers and their trade unions”, (b) “business and industry”, (c) “non-governmental organizations: partners for sustainable development”), (United Nations, 1992).

(iv), 2012, “Rio+20”; “The future we want” The common vision: (a) “...renew our commitment to sustainable development and to ensuring the promotion of an economically, socially and environmentally sustainable future for our planet and for present and future generations.” (b) “...Poverty eradication...“, (c) “we commit to work together to promote sustained and inclusive economic growth, social development and environmental protection and thereby to benefit all.” Additional multitude factors highlighted: democracy, peace, human rights, freedom, security, gender equality,... the negative impacts of climate change affect all countries..., ...more attention should be given to Africa...etc. (United Nations, 2012).

Some more relevant citations from “Rio+20”: “40. We call for holistic and integrated approaches to sustainable development that will guide humanity to live in harmony with nature and lead to efforts to restore the health and integrity of the Earth’s ecosystem.” (United Nations, 2012).

(iv) 2013, September Global Sustainable Development Report (Prototype Edition) “Building the Common Future We Want “Eliminating poverty and hunger; feeding, nurturing, housing, educating and employing 9 billion people; securing peace, security and freedom ;and preserving the Earth’s life support systems in the next two generations”. This report highlights also the multitude of assessments. (United Nations, 2013).

It is apparent that the numbers of factors have grown in the reports above of the United Nations; probably because the reports aim to simultaneously satisfy every perspective of human needs. It is possible to interpret the multitude of statements having political incentives rather than to be motivated from a scientific and technologic background. In public life, Sustainability and Sustainable development are frequently used without strict and coherent definitions. The ideas of sustainability seems initially to focus on the human needs, whereas in the later reports of UN a more altruistic approach of conservation has been accepted; all species have a value of its own without being directly useful for human production. Maintaining the ecosystem as intact as possible has been incorporated in the recent goals of UN. “Holistic Solutions” are sought between disciplines. A challenge is certainly to attain such “cluster” of goals.

Data collection for statistics has become an important instrument for responding to the goals of UN. Influenced by other countries of OECD, the Swiss institutions BFS, BUWAL, ARE (2003) elaborated a statistical tool based on the AGENDA 21 and the Brundtland-report; statistical indicators within the fields of economics, environment and sociology (in the formulas described as “capital” separated in each perspective) were agreed upon by scholars in settings of work-groups. I have some doubts whether such indicators are useful or not; BFS, BUWAL, ARE (2003) have accepted the view of the three perspectives without analysing why they are relevant or if there might be any contradictions (e.g. contrast economy and environment). In a global context, the complexity of the goals results in biases, i.e. to give favour of

one perspective in the reasoning, e.g. in business related research; Bansal (2005) e.g. investigates “corporate sustainable development” in oil, gas and mining industry were affected by “resource based opportunities over time“, etc.

We realise that the multitude of goals become increasingly complex, which I here suggest is an inhibiting factor and might lead to adverse results. Denzler (2013) proposes a return to the simplistic ideas of von Carlowitz, because nature itself is limited. I remark that the development of the concept of sustainability has developed from being fully focused on the usefulness for humans to also, in recent times, containing an altruistic willingness that e.g. species have a value for their own sake. Indeed, the perspectives of economy and sociology are human constructs whereas nature, with its ecological systems, is there with or without humans. By that reason I contribute with another view in the row of writings in the topic of sustainability; here also connecting to the disciplines of change and facilities management.

3. CHANGE, DECISION, FM AND SUSTAINABILITY

Change in general terms occurs eventually with or without human intervention; change due to human activity has its roots in decisions and perception of needs. The linkage between facilities services and covering various needs has multiple perspectives, (Finch, 2012). Appropriate decision making should not be matched to short-sighted organisational needs but to the surrounding world itself; Dettwiler (2012), stresses the alternatives in decision making namely that of “not making a change at all” and also that of “retarding the change to an optimal time in the future”. Such analytical work gives better preconditions for optimisation of use, activities and material flow. Activities indeed have particular significance in FM; Junnila (2004) “...facilities related activities are a significant factor to consider when establishing environmental strategy..”

LEED, BREEAM, DGNB are abbreviations of some organisations that are specialised to certify buildings having fulfilled stipulated sustainability criteria, addressing management of building materials and energy consumption etc. Such certification organisations base their stipulated criteria from research and practice; on the web-page of BREEAM (2013) it is written: *A number of public and private sector organisations specify or encourage the use of BREEAM to help minimise the sustainability impacts of their buildings.*”. It is difficult to find an analysis of biases that might occur in such mixtures of stakeholders (as it is also in the UN reports). A fundamental question is however; are such certificates in reality beneficial for attaining goals of “true” sustainability? Contrarily, the risk of adverse results should not be neglected because companies that have obtained some kind of “green” certificate have consequently less incitement to make additional sustainable efforts outside the requirements. Such implications are further discussed below in the analysis.

Lavy and Fernandez-Solis, (2009), investigated the FM-professionals’ perception of the importance to fulfil criteria according to LEED, which confirms my critique to the use of the term sustainability indicating that it tend to be a psychology (subjective) related rather than science related. Thus if we just “feel” having done a sustainable change it is not obvious that we will have done something sustainable in an objective and scientific sense.

In the search for a deeper understanding of the subject, and the particular character of FM that to a considerable extent relates to services, a theoretical approach with focus on processes of services and its various flows of materials (goods) is treated in next section.

4. AN EXERCISE OF THE LOGICS OF SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

All the above mentioned texts of UN relating to the concepts have as the common message that the current status of the world is not satisfactory and should be improved in the future. The goals and agreements of the UN reports might be mirrored in set of systems. I try here to simplify the complex problematic to an ecological system as presented in Figure 1. The ecological status is here a result of “What we do” and “What we have”, or, assembled under “A” (Activities) and “G” (Goods). Here I include items like attitudes, conflicts, politics, culture and other human activities under “Sociology”. Themes like “Knowledge” and “Institutions” can be attributed under all items. For the simplification tangible items like cultural heritage is subordinated under “matter” and “animals, plants and humans” certainly under the “biosphere” etc.

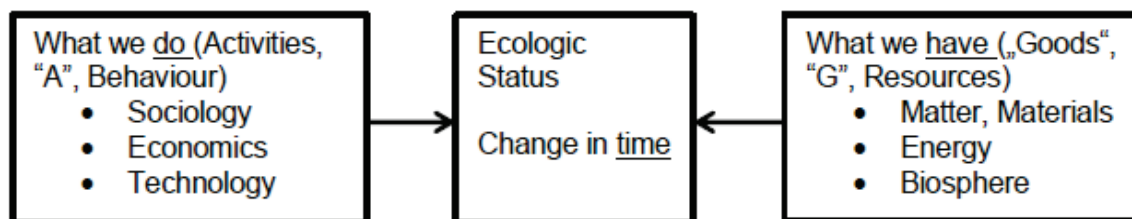
Time and change are inevitable elements of nature and intrinsically interweaved with each other. In order to have a logical starting point in my reasoning below, I propose following hypotheses:

Hypothesis 1: *The ecological status at a specific time is a function of natural processes and what humans have done with the resources until that time”.*

Hypothesis 2: *Every human activity is a contribution to the detriment of the environment.*

Until present time, a posteriori, both hypotheses seems affirmative since I have not found any single example from real life that can reject the hypotheses. Even if the term “detriment” is very marginal caused by a single human (e.g. extent of “consumed” cars, clothes, houses in a lifetime), the total sum of humans causes damage and energy consumption.

Figure 1: A proposed basic model of the ecological system on the planet



The “Ecologic Status” has increasingly been affected by humans since about 30,000 years ago when hunting in larger scale took place, resulting already at that time extinction of species. About 10,000 years ago when agriculture and technologies (making fire, construct buildings) grew in significance; ultimately resulting in a continuous growth of human population and technology on the planet. In Figure 1, I find it motivated not to put the three main perspectives on the same level (as UN does (United Nations, 1987)); “Sociology” and “Economics” should rather be subordinated “Ecology” (the main function of Figure 1) because if humans would disappear from the planet there would still be a kind of “Ecological status” of a presumed reminiscent of the biosphere (affected or not affected by humans at a previous time).

Multiple perspectives are incorporated in the desire to achieved stipulated goals of the reports of United Nations. Since the perspectives and political goals have grown in number the whole problematic has as well become increasingly more complex and thus more difficult to attain. Therefore I attempt to structure the problematic in a mathematic and logic analysis as follows.

The factor *time* is used here to be common factor in the reasoning of achieving sustainability (through sustainable development). Time is as well a common factor in change and activities such as “development” and the linking factor between the two treated concepts.

As a starting point of the analysis I make the presumption of a theoretical Total Sustainability (S_T) as a variable that change in time due to change decisions. The total Sustainability, S_T , is thus composed of a multitude of desired goals, due to the general respect of the Brundtland report; three main perspectives seem to general accepted: (1) ecological (E), (2) sociological (S) and (3) economic (F) perspectives. Certainly a fourth perspective, the Institutional (I) does also play a role, possibly in theoretical research of sustainability. More perspectives (N) can certainly as well be added to S_T . The main perspectives are furthermore composed of numerous subcategories and sub-sub categories etc. Achieving sustainably development implies performing activities (A) through processes (or services) and managing tangible materials (or goods, (G)). “A” and “G” respectively should be understood as “the outcome of “ activities and use of material” within a perspective. The “+” in (1) must be understood as “together with” rather than a pure algebraic expression + because activities and materials have different units of measurements. Thus:

$$S_X = A_X + G_X \quad (1)$$

Semantically (1) can be formulated as: *activities and goods within one perspective that interact*. It must be emphasised that A_X and G_X are assumingly interrelated with another perspectives: A_Y and G_Y ; whereby the activities and material should in principle be subject to partition between the perspectives. (However in one dimension the carbon footprint could function as a common denominator, as applied in LCAs).

A first step of a logical analysis would be to transfer the ideas to a viewpoint of set theory. Ideally it would mean that $S_{T\cap}$ is the intersection all perspectives. Studying the reports of United Nations one can assume that the ultimate goal could possibly be expressed as:

$$S_{T\cap} = S_E \cap S_S \cap S_F \cap S_I \cap S_N \quad (2)$$

Remarkably, the multitude of political desires in particular in “Rio+20” gives the opposite extreme of sustainability, S_{TU} which seems to be diluted to unify all perspectives instead of intersecting them:

$$S_{TU} = S_E \cup S_S \cup S_F \cup S_I \cup S_N \quad (3)$$

Intermediary states between the extremes of (2) and (3) might be more realistic (S_R) with combinations of so-called subsets (\subseteq) and supersets (\supseteq) would appropriate to consider. Certainly, a challenge is to render such ideas more operational, realizable and also publically understandable. This essay omits deeper studies of interrelated factors between the perspectives. However the ubiquitous use of Sustainability and its adjective “Sustainable” (often

without substantial proof of having such quality), one can understand that another notion is prevailing in the society than that of the goals of United Nations; various stakeholders attributing themselves to be sustainable or to contribute to a sustainable development without taking (2) into consideration.

Consequently the question has relevance here whether the non-intersected parts impinge and function as counterproductive forces. What implications do the A's and G's outside the intersection of (2) have when they interplay? A difference could be:

$$S_{TA} = S_{TU} \setminus S_{T \cap} \quad (4)$$

($S_{TA} = S_{TU} \setminus S_{T \cap}$, “\” meaning the difference). We will see later in this essay (Table 1) that omitting parts of (2) might in fact have adverse results of attaining sustainability.

Another relevant question: Is Sustainable development and Sustainability achievable by voluntarily renouncing from one perspective (x) in (1)? If “yes” then:

$$S_T = \exists(A+G)_X \vee (A+G)_N, \quad (5)$$

suggesting that S_T is a true statement even if a factor should not be sustainable *per se*.

Conversely:

$$S_T = \exists(A+G)_X \wedge (A+G)_N, \quad (6)$$

suggesting that S_T is false statement if one perspective is lacking (because interaction between perspectives takes place).

As an example of (5) and (6) can be expressed as an investment in an office building, constructed with sustainable materials with reduced energy consumption (sustainable HVAC) and where the return of investments (ROI) also fulfil the expectations. The building is however planned in an inflexible way and disadvantageous located, resulting in a considerably reduced usability because it cannot be used as long as planned. (5) is valid if it is possible to move (deconstruction, recycling etc.) the building to a more appropriate place and conversely (6) is valid if the building cannot be moved due to the concrete design structure. Here it is evident that time becomes a dependent variable because (5) and (6) can swing to opposite statements in course of successive events, which can be observed in following sections.

5. LINKING SUSTAINABILITY TO PERSPECTIVES

Assuming that in reality there are additional factors that cannot immediately be addressed to the three considered perspectives. By that reason a Rest perspective, R, should favourably be added; both before change because one can assume if a change is not taken place the value of S (0) will be affected. R ((7) and (8)) below) includes additional perspective like Institutional (S_I) perspective that sometimes is argued should be the fourth perspective. In fact even more perspectives could be plausible. Another Sustainability perspective that is relevant for the particular field of Construction and FM as follows:

- Usability (S_{FM1}): How usable is a building or physical after construction or refurbishment?
- Services (S_{FM2}): How does for example the maintenance change in time, with its connected activities (e.g. service changes that imply other commuting distances (carbon footprint), scale effects at service deliverer etc.)
- Material (S_{FM3}) (goods): life-cycle of materials, propensity to re-use in other constructions
- Carbon footprint of a specific construction/not-to-construct decision (S_{FM4})
- Pollution footprint of a specific construction/non-to-construct decision (S_{FM5})
- Etc. (S_{FMn})

In a simplified model such perspectives might have its place under mentioned “R” above.

Even if multiple perspectives can be related to the concept of sustainability, it seems that the three perspectives of sustainability dominate the common understanding: environmental (e), sociological (s) and economical (f) perspectives. In order to render the set theory formulas above into calculable following formulas equations are deduced: (7) and (8) illustrates the three weighted perspectives with a weighted rest (containing e.g. institutionalised perspective). The difference in time, t , of (7) and (8) is what we can define as a change. Thus at time 0 the sustainability would be

$$S(0) = w_{E0}S_E(0) + w_{S0}S_S(0) + w_{F0}S_F(0) + w_{R0}R(0) \quad (7)$$

And when time t has elapsed, the sustainability (and thus the sustainable development)

$$S(t) = w_{Et}S_E(t) + w_{St}S_S(t) + w_{Ft}S_F(t) + w_{Rt}R(t) \quad (8)$$

Assigning “Sustainability” and “Sustainable Development” as indicator for having achieved goals of United Nations or not, following criteria (a and b) could logically be stipulated:

Criteria a: If $S(0) \geq S(t)$ then a change would be void of sense in terms of defined variable of Sustainability.

Criteria b: If $S(0) < S(t)$ then a change is favourable for the sustainability and can be assigned as “sustainable development” at time t .

The weighting in (7) and (8) have the sum 1 as “ $w_{E0} + w_{S0} + w_{F0} + w_{R0} = 1$ ” and “ $w_{Et} + w_{St} + w_{Ft} + w_{Rt} = 1$ ” respectively; weighting is the proportion between the perspectives. Assigning appropriate values to R and w is indeed problematic that relies on forecasts and historic data; it would therefore be a challenge *per se* how the weighting should be operationalized; subjective attitudes oppose deeper analysis of longitudinal observations.

6. PRACTICAL IMPLICATIONS: A NEW APPROACH OF SUSTAINABILITY ANALYSIS

Scientific publications on measuring the various impacts on sustainability are predominantly focused on specific disciplines and resources. Matthews *et al.* (2008) and other scholars in the field have given critique to the current methods of calculating the carbon footprint because the entire supply chain cannot be covered sufficiently in Life cycle assessments (LCA). As a

specific case within sustainability, Dettwiler (2013) identified the negative effects of building activity as result of governmental decision to attain a “2000-Watt Society” (www.novatalantis.ch) ; which implied massive refurbishments and replacements of old windows by new ones (often with plastic windows frames) (Table 1).

Mattews *et al.* (2008) emphasised that even if analyses are pursued with e.g. carbon print calculations of such decisions, these tend to be insufficient. According to Table 1, post-secondary effects are not likely to be taken frequently into consideration. Table 1 illustrates the dynamics of the flow of goods and related activities with the formula (7) and (8) above. Stakeholders motivate such goals by monitoring in the first place *The Primary effects*, which are public predominant; whereas the side effects (secondary, tertiary etc. effects.) are seldom highlighted.

Table 1: Multiple Effects of the decision to replace old windows with plastic windows regarded in the four sustainability perspective, regarded into aspects of G (Goods) and A (Activities).

	Environmental (E)	Social (S)	Economic (F)	Rest (R)
Primary positive effects, (Official), primary argument by decision makers, (α)	G: Improved building physics: acoustic, energy insulation (heating, cooling) A: New knowledge skills in R&D in new windows	G: Newer look, transparency, easiness to clean and use, higher satisfaction A: Creation new jobs, directly and indirectly, Easier maintenance,	G. Reduced Energy Cost for the owners. A. Emerging firms in manufacturing new windows, financial growth. Promotion of refurbishment (cheaper loans)	G: Technology parallels (generic technology) , application of innovation. A: Societal imitation energy saving (educational effects)
Secondary, often negative effects, (Less considered), (β)	G: Some windows (plastic, aluminium) cannot be repaired, maintained, Resource use A: Disposal to waste activity, CO2 increase (e.g. transports)	G: Individual variations disappear of windows A: Users dissatisfaction of new windows and loss of old ones.	G: Short life cycle reducing substance value of real estates. A: Governmental requirements for not desired, radical refurbishments (more expensive loans for non-refurbished houses)	G:EoS lead to standardisation not fulfilling special design. A: Loss of skills and jobs (poverty) in manufacturing, repair, maintaining timber framed windows
Tertiary Effects etc., Institutional (Even less considered) (β)	G: Bounded life-cycle (25 years), dependence to regular replacement and waste A: Higher societal energy use (and pollution) than for the individual owner of the building	G: Monoculture takes over regional variations (Architecture) Loss of cultural heritage A: New patterns of Service related to windows>societal indirect effects.	G: Economics of Scale (EoS) of new plants for manufacturing. Disadvantageous dependencies. A. New patterns of Service related to windows>transaction costs (contracts).	G: Spaces with new energy-saving windows got heating unnecessarily. A: New R&D in total creates a consumption pattern of resources (like oil) more than before the decision.

Table 1 should be regarded a basic assumption of a case, where materials and service are highlighted within the four perspectives. When operationalized, data collection and various estimation methods may give input for values for the weights. The secondary and so forth side effects (β) can be regarded a not sufficiently investigated “black box” for example LCAs (Mattews *et al.* (2008)).

7. A DRAFT FOR A GENERAL THEORY AND UNDERSTANDING

The example above suggests that consequences and awaited advantages ($s\alpha$) are most likely to be considered without analysis of indirect and secondary consequences ($s\beta$) of a taken decision. As said, actors between above mentioned perspectives interact not only within the same perspective, but also between others. The sum of the sum etc. of consequences could possibly be described according to the general description of multiple integrals, the Riemann integral as consequence of (2) above, as $F(x) = \int \dots \int_T f(x_1, x_2, \dots, x_n) dx_1, \dots, dx_n$, which cannot be rendered operational. In order to attain a more comprehensive idea to the problem, a simplified formula (9) expressing the current principles of sustainability (assembling all perspectives in (7) and (8)) is suggested sustainable development as follows:

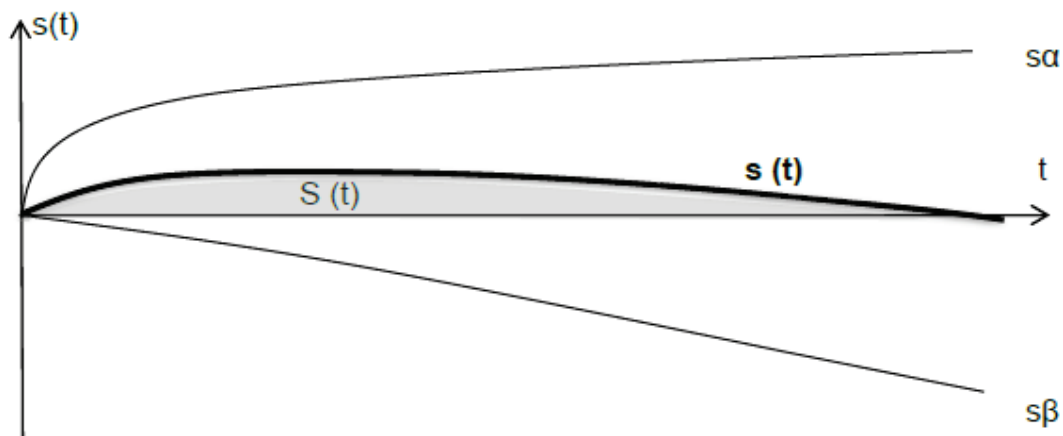
$$s(t) = s\alpha(t) - s\beta(t), \quad (9)$$

and the Sustainability also as a function of t

$$S(t) = \int_0^t s(t)dt, \text{ where } S(t) > 0 \quad (10)$$

The sign of minus“-“in (9), must not necessarily be understood as neither geometric nor algebraic middle between $s\alpha$ and $s\beta$ because means between functions are subject to theorem discussions. Instead, (9) and (10) should be understood as principle relationships and can also be illustrated in a figure as a general scenario (Figure 2). At time 0 the change decision is about to be taken, also t -axis is placed where sustainability is zero.

Figure 2: Sustainable development expressed as a function ($s(t)$)



In Figure 2, the surface $S(t)$ functions as the accumulated sustainability on a time-scale with possible analysis at any time on t . Ideally a thorough LCA should land close to the graph $s(t)$, however today is likely to land in-between $s\alpha$ and $s(t)$. For example, as discussed above, a danger with certification in construction sector, is that stakeholders are satisfied when obtaining a stipulated step of certification; $s\alpha$ is primarily respected but neglecting the secondary effects, $s\beta$, leading to a false assumption that $s(t) \approx s\alpha$.

Referring to Hypothesis 2 above, $s\beta$ would probably have a shape similar as proposed even if there might be cases where secondary (and so forth) effects in singular cases can demonstrate a positive value, $s(t_n) > 0$.

8. CONCLUSIVE DISCUSSION

This essay should be regarded as a contribution to the current debate on sustainability. It is a challenge to unify the complex intentions of the U.N: As discussed above, the indirect consequences should preferably be paid more attention than today (Table 1). It is out of the human capacity to take every aspect of a change decision into consideration when sustainability measures shall be taken. Similarities can be given to the utopia of creating a perfect weather forecast, which as far is impossible (chaos theory). Apparently, the two treated concepts (sustainability and sustainable development) are generally subjectively used rather than objectively used. As a result of the analysis made above, a more objective mathematical-logic understanding is suggested of the problem, rather than the political and subjective arguments of today. Assumingly, some of the relatively simple and possibly more objective ideas from 1713 of von Carlowitz could favourably be re-implemented, also in the context of today. Even if the complexities of the two concepts are not comprehensible, this essay argues to avoid an uncritical use of the terms “Sustainability” and “Sustainable development” without deeper analysis of described secondary consequences (and so forth) and effects. As described above, Goods (G) and Activities (A) are suggested to facilitate analysis of the two concepts. Instead of assigning the concepts as absolute terms, I suggest to regard the treated concepts as variables.

Considering the reasoning above, following strategic approaches among decision makers for the future are suggested as:

- Enhancing the capability to distinguish the differences between efficiency and effectiveness; i.e. doing things right vs. do the right things, is as well most significant in decision of change that support suggested idea of formula (10) above.
- Considering the idea: “Reduction of the damage in an optimal way”, which would be more appropriate, instead of steadily using “sustainability”. In the future, ICT that is able to process increasingly amount of data (with scenario generation etc.) and BIM (Building Information Modelling) could favourably be incorporated in DSS (Decision Support System) for decision making in sustainability related problems.

REFERENCES

- Arrhenius, S (1896), On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground, *Philosophical Magazine and Journal of Science*, Series 5, Volume 41, pp. 237-276.
- Bansal, P. (2005), Evolving Sustainably: A Longitudinal Study of Corporate Sustainable Development, *Strategic Management Journal*, Vol. 26, pp.197–218.
- BFS, BUWAL, ARE (Eds.), (2003), *21. Nachhaltige Entwicklung und regionale Disparitäten, Schlussbericht Methoden und Resultate*, Neuchâtel.
- von Carlowitz, H. C. (1713), *Sylvicultura oeconomica oder Haußwirthliche Nachricht und Naturmäßige Anweisung zur Wilden Baum-Zucht*, (Ed.) Johann Friedrich Braun, Leipzig.
- von Carlowitz, H.C. (2013) , (2nd. Ed.) (Ed. Hamberger, J.) *Sylvicultura oeconomica oder Haußwirthliche Nachricht und Naturmäßige Anweisung zur Wilden Baum-Zucht*, oekom verlag, Munich.
- Denzler, L. (2013), Plädoer für die Rückbesinnung auf den Kern der Nachhaltigkeit (Essay), *Perspectiven*, Vol. 164, pp. 212-215.

- Dettwiler, P. (2012), The Change Management Challenge in Growth Firms, IN *Facilities Change Management*, (Ed. Finch, E.), Blackwell Publishing, Oxford. pp. 42-56.
- Dettwiler, P. (2013) Factors Threatening the Cultural Heritage- the Windows of Europe, *Proceedings Facilities Management and Maintenance*, World Building Congress, CIB, Queensland University of Technology, Sustainable Built Environment, Brisbane 5-9 May 2013, Publication 385, pp.49-60.
- Finch, E. (2012) (Ed.), *Facilities Change Management*, Wiley-Blackwell, Oxford.
- Fourier, J.B.J., (1827). Mémoire Sur Les Températures Du Globe Terrestre Et Des Espaces Planétaires. *Mémoires de l'Académie Royale des Sciences* Vol. 7, pp.569–604.
- Junnala, S. (2004), The environmental significance of facilities in service sector companies, *Facilities*, Vol. 22, No. 7/8, pp. 190-198.
- Lavy, S. and Fernandez-Solis, J.L. (2009), LEED accredited professionals' perceptions affecting credit point adoption, *Facilities*, Vol. 27 No. 13/14, 2009, pp. 531-548.
- Matthews, H.S. , Hendrickson, C.T. and Weber, C.L. (2008), The Importance of Carbon Footprint Estimation Boundaries, *Environmental Science & Technology*, Vol. 42, No. 16, pp.5839–5842.
- Tanzil, D. and Beloff, B. R. (2006), Assessing impacts: Overview on sustainability indicators and metrics. *Environmental Quality Management*, Vol. 15, pp. 41–56.
- United Nations (1972), REPORT OF THE UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT, <http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97>, (accessed 29 November 2013).
- United Nations (1992) *AGENDA 21, Conference on Environment & Development Rio de Janeiro, Brazil*.
- United Nations (2012) Rio+20, 66/288. *The future we want, Resolution adopted by the General Assembly on 27 July 2012*,
- United Nations (2013), Prototype Edition, Global Sustainable Development Report *Building the Common Future We Want*, Executive Summary
- WCED (1987), *Our Common Future*. Oxford University Press: Oxford.
- <http://www.breeam.org/podpage.jsp?id=273>, (accessed 29 November 2013).
- <http://sustainabledevelopment.un.org/content/documents/975GSDR%20Executive%20Summary.pdf> , (accessed 29 November 2013).
- http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/66/288&Lang=E , (accessed 29 November 2013).
- <http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97> , (accessed 29 November 2013).
- <http://www.novatantis.ch/fileadmin/downloads/2000watt/Weissbuch.pdf> (acc. 26 Feb. 2014)

8.2

INTERNATIONAL TRENDS FOR SUSTAINABILITY IN FM: EVALUATION OF POLICY AND FM COMPETENCE IN NORWAY AND UK

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ABSTRACT

Purpose: The purpose of this paper is to describe the evaluation and integration of national approaches into an international strategy for sustainability in Facilities Management (FM). The FM profession is at the forefront of delivering sustainable practices to support the core business of organisations on all management levels.

Background (state of the art): Sustainability is at the top of the European FM research agenda. In several European countries, the topic has emerged and is developing as a core business strategy and an obligation for public and private organisations.

Approach (Theory/Methodology): A UK questionnaire survey was transferred into the context of Norwegian FM practice to examine how FM professionals in Norway engage with sustainability in FM. The survey was conducted with support of the Norwegian FM Network (NfN) and results from UK and Norway have been analysed comparatively.

Results: The paper provides insights into the relevant similarities and differences in the issues and trends influencing sustainable policies and practices in both Norway and the UK. Practical implications: FM professionals can enhance their competencies in dealing with the challenges posed by the sustainability agenda.

Research limitations: The survey was conducted among professional facilities managers in only two countries.

Originality/value: The results provide valuable information on the overall impact of the sustainability agenda on facilities managers' professional work. Similarly, for FM professionals, information is provided to enhance the competences of facilities managers for dealing with sustainability issues.

Keywords: FM qualification, FM strategy, International education, Sustainable facilities management, Sustainability policy

1 INTRODUCTION

The purpose of this paper is to contribute to the development of an internationally applicable sustainable facilities management (SFM) strategy for facilities management (FM) in research, education, and practice. The research focus is on the evaluation of current policy and competence in sustainability in FM. Approaches from the FM profession have been studied in Norway against the background of information from surveys conducted in the UK and the state-of-the-art literature review on international level.

Researchers from the University of Reading (UK) and the British Institute of Facilities Management (BIFM) have studied sustainability in FM in the British FM industry by conducting seven surveys between 2007 and 2013. In 2013, the latest results of long-term research in the field of sustainability in FM were presented at the CIB World Building Congress 2013 in Brisbane, Australia (Elmualim 2013). This event has since become the starting point for co-operation between the research groups at the School of Construction Management and Engineering at the University of Reading, and at the Centre for Real Estate and Facilities Management at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway.

The objective of the paper is to further develop and internationalise the national approaches and contribute to the advancement of knowledge in SFM. The research focus is on the evaluation of policy and FM competence in Norway and a discussion of similarities and contradictions between Norway and UK to further inform a state of the art review and understanding of SFM on an international level.

2 STATE OF THE ART

Since 2004, sustainability in FM has become a topic of research in the Nordic countries, as exemplified by two publications: ‘Sustainable FM – a new field of research and practice’ (Jensen & Nielsen 2008) and ‘Managing facilities in a Scandinavian manner’ (Elle *et al.* 2004). Elle *et al.* (2004, 13) emphasise the focus on environmental issues: ‘In the Scandinavian context, the main focus has been on environmental sustainability’, and this focus has been further developed by Nielsen *et al.* (2009, 1), who stated that ‘Sustainable facility management (SFM) is an “umbrella” for various ways of reducing flows of energy, water and waste in the daily operation of the buildings, for instance by regularly monitoring the consumption, by using “green accounting”, by applying policies for sustainability, enhanced user awareness etc.’

In 2013 a literature research was conducted using the search engine Google Scholar.¹¹ The results revealed a relatively small but increasing number of publications, identified with the keyword phrase ‘sustainable facilities management’. The total result of 83 matches for the period 2007–2013 included the following 10 scientific papers, in which both the titles and the

¹¹ Available at: <http://scholar.google.com> (accessed 9 November 2013)

authors' affiliations demonstrate contributions to the international trend in SFM: 'Ergonomics and sustainability' (Haslam & Waterson 2013), 'Innovation characteristics and intention to adopt sustainable facilities management practices' (Lee & Kang 2013), 'Facilities management driving green building certification: A case from Finland' (Aaltonen et al. 2013), 'The strategic facilities management organisation in housing: Implications for sustainable facilities management' (Nielsen et al. 2012), 'Developing a sustainable approach to corporate FM in Nigeria' (Adewunmi et al. 2012), 'Sustainable facilities management within event venues' (Koukiasa 2011), 'The developing use of strategic alliances in facilities management' (Pitt *et al.* 2011), 'Barriers and commitment of facilities management profession to the sustainability agenda' (Elmualim *et al.* 2010), 'The practice of sustainable facilities management: Design sentiments and the knowledge chasm' (Elmualim *et al.* 2009), and 'Sustainable FM – a new field of research and practice' (Jensen & Nielsen 2008).

In 2010, sustainability was at the top of the research agenda formulated by the research group of the European Facility Management Network (EuroFM). In the same year, EuroFM identified the 10 most relevant FM research fields by conducting a survey among 22 member universities and universities of applied sciences from 10 European countries. The purpose of the survey was to obtain an overview of the institutions' future research objectives, existing research capacities, planned projects, and concrete proposals. A structured questionnaire was sent to the research group members. The response rate was very high. In total, researchers from 9 countries returned 17 questionnaires and made 215 individual contributions to the FM research agenda. The results were used to prioritise the 10 most relevant FM research fields, as follows: (1) 'Sustainability', (2) 'Knowledge', (3) 'Added value', (4) 'Workplace', (5) 'Demand and supply', (6) 'Built environment', (7) 'Usability', (8) 'Future', (9) 'Health care', and (10) 'Work organisation' (Junghans 2012).

3 APPROACH

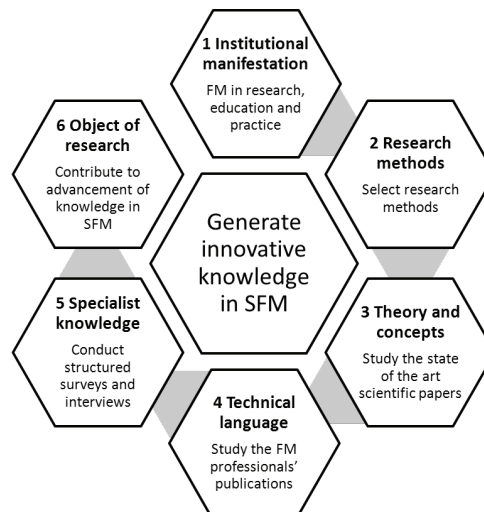
3.1 Theory

The research framework is structured in six fields contributing to the generation of innovative knowledge in SFM. This framework integrates different perspectives based on six characteristics: object of research, specialist knowledge, theory and concepts, technical language, research methods, and institutional manifestation. These characteristics were introduced by Krishnan (2009) and have since been applied by Junghans & Olsson (2012) to describe and discuss the development of facilities management as an academic discipline. The framework has been applied to the SFM research approach with the following partners and assumptions (Figure 1):

1. Institutional manifestation: research, education, and practice in FM have a typical institutional manifestation. Research and education are conducted at universities, such as the Norwegian University of Science and Technology (NTNU) and the University of Reading. Professional FM associations represent the profession. Supporting partners are the British Institute of Facilities Management (BIFM) and the Norwegian FM Network (NfN);
2. Research methods: A structured survey and systematic literature research were selected as the most appropriate methodologies according to the scope and focus of the SFM research project;
3. Theories and concepts: Scientific publications describe theories and concepts that can organise the advancement of specialist knowledge effectively;

4. Technical language: Standards and the state of the art literature review in professional FM publications to use specific terminologies and a technical language;
5. Specialist knowledge: FM experts in research and education as well as professional facilities managers have specialist knowledge and have been involved in the development of the survey and its execution;
6. Object of research: Sustainability in FM is the particular object of research steering the development of an international strategy for SFM.

Figure 1: framework to generate innovative knowledge in SFM



3.2 Methodology

The annual BIFM survey of sustainability in FM

Singh & Elmualim (2012, 3) describe the objective of the BIFM's annual survey of sustainability in FM as 'to] examine and track trends in environmental responsibilities, energy management, waste management, carbon footprint management, water management, response to legislation, sustainable use of resources among Facilities Managers'.

In 2012, the BIFM administered an online questionnaire survey among facilities managers that were members of the institute as well as among other interested FM professionals. The target group was 1200 facilities managers with responsibility for sustainability development and implementation. The duration of the online survey was 10–30 April 2012. In total, 203 respondents completed the questionnaire. In cases where respondents did not provide a response to a question, they were excluded from the analysis of that particular question. Comparability with previously conducted surveys is limited because data related to all questions is not available for all years. Further, the number of respondents from earlier surveys varied between 268 in 2010, 222 in 2009, 168 in 2008, and 251 in 2007. The 2012 survey was conducted anonymously and the respondents were self-selected. Hence, the results of the survey may only represent the opinions of facilities managers that are interested in sustainable FM (Singh & Elmualim 2012; Elmualim 2013).

The Norwegian sustainability in the FM survey

The objective of the survey in Norway was an evaluation of similarities and differences between the national approaches in UK and Norway in order to contribute to an international strategy for sustainable FM. Key questions of the BIFM survey of sustainability in FM for

2012 (Singh & Elmualim 2012) were selected and statements developed to examine how FM professionals in Norway engage with sustainability in their business environments. The questionnaire was translated from English into Norwegian.

An online survey was conducted, with a questionnaire sent to facilities managers. The questionnaire was distributed by the Norwegian FM Network (NfN) and administered by the Centre for Real Estate and Facilities Management at NTNU. The NfN sent the questionnaire to all of its 45 member organisations. The target group was 45 facilities managers that represented the members of the NfN. The duration of the online survey was four weeks during September and October 2013. The responses rate was 68%, with completed questionnaires returned by 31 respondents. In cases where respondents did not provide a response to a question, that respondent was excluded from the analysis.

The Norwegian survey's comparability with the BIFM sustainability in FM survey conducted in 2012 and earlier BIFM surveys conducted in the UK is limited because data related to all questions are not available for all years. However, the response rate in Norway was very high, and the total number of respondents relatively small compared to the UK. The survey was conducted anonymously, but the respondents were personally invited and not self-selected. The results of the survey therefore represent the opinions only of Norwegian facilities managers who are members of the NfN.

Transferring the British survey into the Norwegian survey

The theoretical framework was used to consider all relevant fields of the generation of innovative knowledge in SFM, which is considered 'the object of research'. The research focus of this paper is as follows: a literature research and study of theory and concepts related to SFM; the NfN understanding of the British 'technical language', and translating the key terms into the Norwegian terms of technical language; and gathering 'the specialist knowledge' from Norwegian facilities managers and comparison with specialist knowledge in UK. The planning, execution, analysis, and interpretation of the survey results included the following work phases:

1. Clarifying the state-of-the-art theory and concepts: (i) literature research and overview of theories and concepts used in survey development in UK; (ii) developing a common understanding of theory and concepts and technical language used in the questionnaires.
2. Transferring British surveys to the Norwegian context: (i) discussions with Norwegian FM experts to clarify survey possibilities in the Norwegian context; (ii) selection of key questions and statements from the British survey; and (iii) translation of the questionnaire into the Norwegian context and the Norwegian language.
3. Execution of survey in among members of the Norwegian FM Network (NfN): (i) develop an online survey version with the use of appropriate software; (ii) test the online survey on a group of Norwegian-speaking experts and consider improvements; (iii) reach agreement on the best way to contact interviewees and send e-mails to NfN members as well as reminders after an appropriate time; and (iv) evaluate feedback, analyse the rate of respondents' feedback, and prepare documentation of survey results.
4. Comparative analyses of results from Norwegian and British surveys: (i) describe the structure of British surveys and the focus of their questions; (ii) analyse results from the British surveys; (iii) describe the structure of Norwegian surveys and the focus of

the questions; and (iv) discussion of similarities and differences between Norwegian and UK surveys.

4 RESULTS

4.1 SFM evaluation of policy and FM competence in the UK

The first questionnaire survey targeting practising facilities managers was developed and conducted in 2007 with the support of the British Institute of Facilities Management (BIFM) in the UK (Elmualim *et al.* 2010). Between 2007 and 2013, the development of sustainability in FM was continuously studied by conducting seven questionnaire surveys in cooperation with the BIFM, annually. The changing economic and political context required continuous development and adaptation of the questionnaire survey to meet the changing demand of the FM industry. Singh & Elmualim (2012, 1) considered the importance of studying SFM by referring to the argument that the economic crisis and rising environmental pressures and legislations enhanced the need for organisations in all sectors of the economy to act sustainably: ‘Within the built environment, facilities managers (FM) are best positioned to leverage the sustainability agenda for organisations.’ In a different economic context, Facilities management has been considered as one of the fastest growing professions in the UK (Elmualim *et al.* 2010), and as having a ‘great role in contributing to the reduction of the built environment impact on the environment’ (Elmualim *et al.* 2010, 58).

In 2012, the revised version of the questionnaire survey included 23 questions targeting the evaluation of sustainability policy and FM competence with four focus areas (Singh & Elmualim 2012), which are described in more detail below.

Sustainability policy and management of reporting – Questions and Answers (Q&A)

The first sequence of eight questions in the 2012 survey was targeted at gathering information about the organisations’ SFM policy and reporting by evaluating the importance (Q1), economic impact (Q2), scope (Q3), effectiveness (Q4), and aspects of sustainability covered (Q5). A clear majority of 90% of the respondents agreed that sustainability issues were of high importance to their organisations (A1). The economic crisis had not impacted their sustainability focus (A2), and 90% of the respondents organisations had a sustainability policy in place and more than 50% understood the terms corporate social responsibility (CSR) and environmental and sustainability policy as synonymous (A3). Most of the respondents believed that their organisations were effective in implementing their policy (A4). In the opinion of more than 90% respondents, the most important aspects covered by the sustainability policy were building energy consumption, waste disposal, water consumption, and business travel using company cars (A5).

The next three questions focused on SFM reporting by identifying stakeholder groups (Q6), the method of reporting (Q7), and aspects of the sustainability reported (Q8). The employees and clients or customers were the main stakeholder groups reported by the respondents’ organisations (A6). Some preferred to produce a single annual report while others preferred to report on their company’s website or intranet (A7). The respondents believed their organisations did not report on building disposal, working arrangements, biodiversity, or furniture disposal. Energy and waste management were focal points of the reports because companies had to report on their carbon footprint (A8) (Singh & Elmualim 2012, 11–27).

Performance of sustainability activities – Questions and Answers (Q&A)

The second sequence of six questions in the 2012 survey evaluated the management of carbon footprint aspects in the studied organisations (Q9), and in their supply-chain (Q10), registration of their carbon reduction commitment (CRC) (Q11), effectiveness of managing sustainability responsibilities (Q12), and barriers to and drivers for the implementation of sustainable practices (Q13 and Q14 respectively).

The majority of respondents believed their organisations managed carbon footprint aspects effectively (A9). A minority believed their organisations were effective in the management of their chain supply (A10), registration of their CRC (A11), their sustainability responsibilities (A12), and the barriers to and drivers for the implementation of sustainable practices (Q13 and Q14 respectively) (Singh & Elmualim 2012, 31–38).

Facilities Managers responsibility on sustainability issues – Questions and Answers (Q&A)

The next two questions in the 2012 survey clarified the respondents' role in the management of the organisations sustainability responsibilities (Q15) and which aspects of sustainability respondents are responsible for (Q16). For a large number of respondents the management of the organisations sustainability is part of their responsibilities (A15) Waste management and recycling, energy management, health and safety, water consumption and carbon footprint management are most important within respondents' responsibility (A16) (Singh & Elmualim 2012, 28–30).

Demography of respondents focus of questions – Questions and Answers (Q&A)

The last sequence of questions in the 2012 survey evaluated the respondents' organisational background and additional information with focus on the type of organisation (Q17), respondents' BIFM membership status (Q18), and respondents' academic qualifications (Q19), the organisations' role in FM (Q20) and in the economic sector (Q21), as well as the number of employees (Q22) and annual turnover (Q23) (Singh & Elmualim 2012). The majority of respondents were facilities managers (A17) and 98% of respondents were BIFM members (A18). The majority of respondents held a General Certificate of Secondary Education (GCSE) O Level qualification, 20% had a master's degree, and only 0.4% had a doctoral degree (A19). The largest groups of respondents worked in end-user organisations (64%) and FM service provider companies (20%) (A20), 65% of the respondents worked in the private sector (A21). More than 45% of the respondents worked in large organisations with over 1000 employees (A22), the annual turnover broadly represented end-user and FM service provider organisations (A23) (Singh & Elmualim 2012, 4–10).

4.2 Summary of results of the Norwegian FM network survey 2013

The starting point when considering the selection of key questions for the Norwegian questionnaire survey was the overall research objective of evaluating and integrating national approaches into an international strategy for sustainable FM. The survey of how facilities management professionals in Norway engaged with sustainability in their business environments was structured into the following questions:

1. 'In your opinion, how important is sustainability to your organisation?' Over 90% of respondents indicated that sustainability issues were either 'important' or 'very important' to their organisations. An additional 3.2% suggested that sustainability was of 'little' importance and 3.2% indicated that they did not know the importance of sustainability to their organisations.

2. *'Does your organisation have an environmental, sustainability or corporate social responsibility (CSR) policy?'* A total of 74.2% of the respondents indicated that their organisations had an environmental, sustainability, or CSR policy in place, while 19.4% said they organisation did not have such a policy, and 6.5% did not know whether their organisation had one.
3. *'Which of the following aspects of sustainability are covered by the policy and how important are they to your organisation? (You may select more than one option).'* Overall, ethical purchasing (93%), waste management and recycling, energy management, and health, safety, and environment (collectively 86%) were identified by respondents as the four major sustainability issues covered in most policies. Other sustainability issues identified were pollution, training and development, and community engagement and/or involvement (collectively 73%). With respect to the importance of each sustainability issue to the respective organisations, the results varied according to the type of issue. For example, the majority of the respondents indicated that health and safety (80%), waste management and recycling (66%), and ethical purchasing (66%) were 'extremely' or 'very important' to their organisations.
4. *'When considering carbon, which aspects of your carbon footprint are managed by your organisation and how significant are these to your organisation's sustainability agenda?'* The majority of respondents identified water consumption (16), building energy consumption (16), and waste disposal (15) as the key aspects covered by the carbon footprint management strategies in their organisation, and considered the aspects as extremely or very significant. The least-covered aspect was supply chain emissions (2), but the majority believed it was either very significant or important (13).

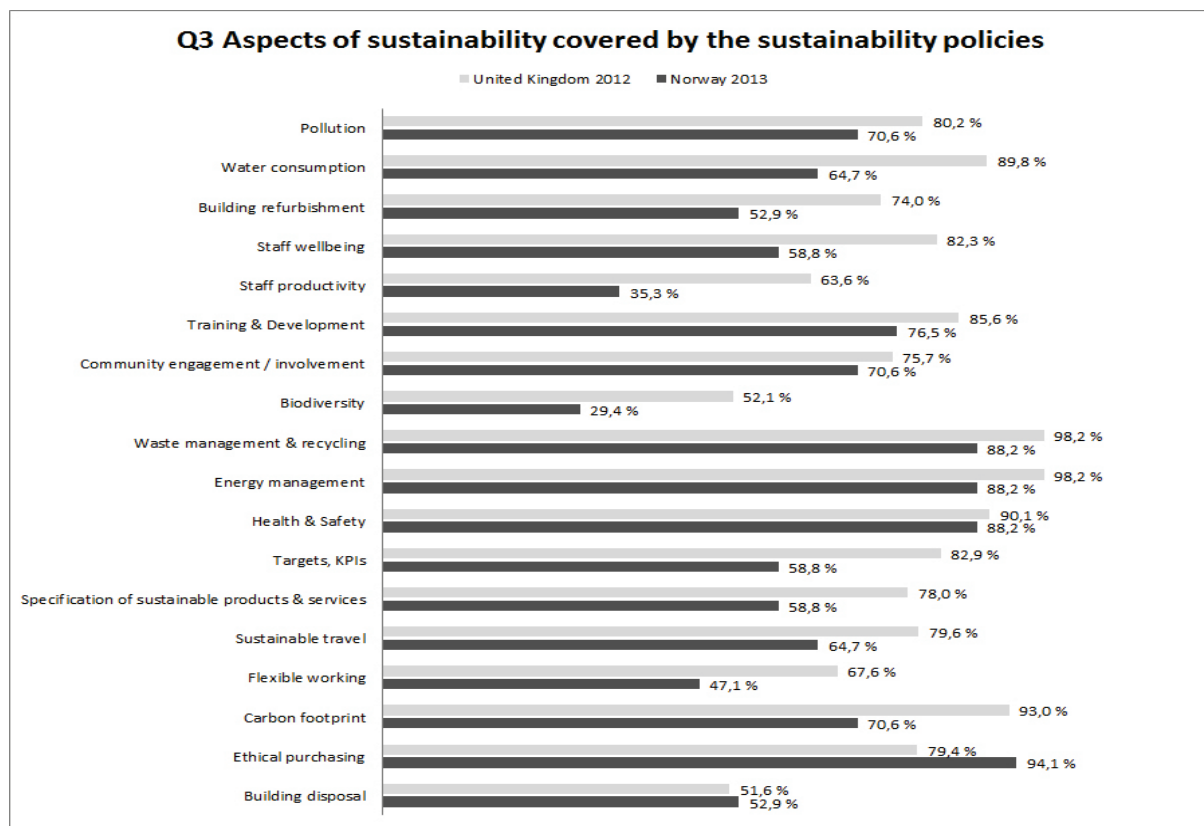
4.3 Norwegian opinions on the British SFM perspective – evaluation of statements

1. *'Sustainability is emerging as a core business strategy and FM professionals are at the forefront of implementing and managing it in the workplace.'* The evaluations of this statement showed a clear trend towards agreement: 35% fully agreed, 60% partly agreed, and 5% disagreed. Regarding the implementation, the opinions showed considerable variation: 25% fully agreed, 50% agreed partly, 10% disagreed partly, 10% disagreed, and 5% neither agreed nor disagreed.
2. *'FM professionals need to develop their understanding of the key issues of sustainability.'* A clear majority of 80% fully agreed with the statement, 15% agreed partly, and 5% disagreed.
3. *'FM professionals need better competence in SFM.'* A clear majority of 85% fully agreed with the statement, 10% agreed partly, and 5% disagreed.
4. *'There is evidence of a gap in the coverage of environmental and social components of sustainability agenda which are most appropriate for the built environment.'* This statement resulted in the greatest variation among the responses: 25% full agreed with it, 35% partly agreed, 10% partly disagreed, 10% disagreed, and 20% neither agreed nor disagreed.
5. *'The most significant barrier to effective management of sustainability responsibilities in organisations is physical constraints, e.g. building structure.'* The responses to this statement showed considerable variation: 15% fully agreed, 40% partly agreed, 25% partly disagreed, and 20% disagreed.

6. ‘The most significant influence driving the implementation of sustainable practices in organisations is corporate image.’ The responses showed a trend towards agreement: 35% fully agreed with the statement, 45% partly agreed, 10% partly disagreed, and 10% disagreed.

In comparing the results between the two surveys with regard to the aspects of sustainability covered by the sustainability policies, the results showed slightly higher response in the UK than in Norway in most aspects including waste management and recycling, energy management and water consumption. Interestingly, only the ethical purchasing and building disposal are ranked higher by respondents in Norway than in the UK as can be seen in Figure 2.

Figure 2: comparison of aspects of sustainability covered in the sustainability policies between the UK and Norway



4.4 Demography of Norwegian respondents

1. ‘Which of the following academic qualifications have you obtained?’ Higher education degrees in Norway and the UK are not comparable. However, 27% responded that they had obtained a bachelor’s degree or equivalent, and 23% responded they had obtained a master’s degree or equivalent. One participant had a doctoral degree.
2. ‘Which of the following best describes your organisation?’ A total of 64% responded ‘end-user’, 32% ‘facilities management company’, 4.55% ‘FM product supplier’, 9% ‘FM service provider’, and none responded ‘consultants’.

3. *‘Which of the following economic sectors best describes the ownership of your organisation?’* The majority of respondents reported that they worked in public organisations (63.64%) and a smaller group worked in private organisations (31.82%).
4. *‘Approximately how many people does your organisation employ?’*
The largest groups of respondents worked in organisations with 1000–4999 employees (27.27%) or more than 5000 employees (36.36%).
5. *‘Approximately, what is the annual turnover of your organisation (end-user only)?’*
Less than 30% respondents answered the question. However, their responses indicated that most organisations had annual turnovers in the range of NOK 500 million and NOK 2499 million [EUR 60.3 million and 301.41million] or more than NOK 10000 million [EUR 1206.15 million].

5 PRACTICAL IMPLICATIONS

In the UK, the survey was conducted for the seventh time since 2007, with responses between 200 and 250 individuals. The respondents were self-selected and not asked to specify their position within their organisation, and they represented the views of facilities managers interested in sustainable FM (Elmualim 2013). The response rate was not very high, given that the British Institute of Facilities Management (BIFM) currently has c.13,500 individual and corporate members (BIFM 2013).

In Norway, the survey was conducted for the first time, with usable responses from 31 members of the Norwegian Facilities Management association (NfN). The NfN currently has 45 corporate members.¹² The NfN members were invited to participate in the survey with support of the NfN board. They were also informed that the survey objective was to compare results of selected questions from the UK survey in a Norwegian context and contribute to further development of international SFM standards.

6 CONCLUSION

Sustainable Facilities Management is evolving as a discipline and becoming increasingly attractive to academics and professionals. Researchers and educators have contributed to the development of SFM scientific theories and concepts in scientific publications. The international literature research revealed a growing number of scientific publications in the timeframe 2007–2013. In the FM profession, awareness of sustainability seems to be independent of economic context. However, the changing economic and political contexts required continuous development and adaptation of the methodological approach in order to meet the changing demands of the FM industry. A questionnaire survey was conducted annually in the UK in the period between 2007–2013. The survey was adapted and used with the FM in Norway to investigate the correlations between research and practice of SFM in the two countries.

¹² Available at: <http://www.nfn-fm.no/om-nfn> (accessed 29 November 2013)

The similarities and differences between SFM policy and competence in Norway and the UK reveal the general transferability of the questionnaire survey. A basic understanding of the terms and definitions is required to translate the technical language from one context to another. The specialist knowledge in different countries is based more on traditions and local practices than on international standardisation.

The target group of the survey was facilities managers. In Norway, the survey participants received personal invitations to participate, while participants in the UK had the option to access the survey online via the BIFM's website and consequently the results tended to show trends and opinions. The next research steps could be to transfer the questionnaire survey to other countries and contribute to the enhancement of specialist knowledge and a common understanding of the technical language.

Further research is required on the implementation of international theory and concepts in highly complex sustainable facilities management approaches. There is a need to broaden the focus of the questionnaire survey towards a more strategic level and consider interaction with core businesses. The authors' assumption is that SFM could be very effective on a strategic level by developing flexible workplace concepts and contributing to the reduction of used building space. The target group of a broader questionnaire surveys should include other stakeholders from the building life cycle, such as architects, engineers, clients, customers, and interested groups.

REFERENCES

- Aaltonen, A., Määtänen, E., Kyrö, R., Sarasoja, A.L. (2013) 'Facilities management driving green building certification: A case from Finland' *Facilities* 31:7/8, 328–342.
- Adewunmi, Y., Omirin, M. & Hikmot, K. (2012) 'Developing a sustainable approach to corporate FM in Nigeria' *Facilities* 30:9/10, 350–373.
- BIFM (2013) *2013 Sustainability in Facilities Management Report*. British Institute of Facilities Management (BIFM). Available at: <http://www.sustainabilityinfmt.org.uk/news/view/40> (accessed 14 November 2013).
- Elle, M., Engelmark, J. & Jørgensen, B. (2004) 'Managing facilities in a Scandinavian manner – Creating a research agenda', *Facilities* 22:11/12, 311–316.
- Elmualim, A. (2013) 'Sustainability in FM: Trends in policy and FM competence consequences'. Paper presented at CIB World Building Congress 2013, 5–9 May 2013, Brisbane, Australia.
- Elmualim, A., Czwakiel, A., Valle, R., Ludlow, G. & Shah, S. (2009) 'The practice of sustainable facilities management: Design sentiments and the knowledge chasm', *Architectural Engineering and Design Management* 5:1, 91–102.
- Elmualim, A., Shockley, D., Valle, R., Ludlow, G. & Shah, S. (2010) 'Barriers and commitment of facilities management profession to the sustainability agenda', *Building and Environment* 45:1, 58–64.
- Haslam, R. & Waterson, P. (2013) 'Ergonomics and sustainability', *Ergonomics* 56:3, 343–347.
- Jensen, P.A. & Balslev Nielsen, S. (2008) 'Sustainable FM – a new field of research and practice', Available at: http://orbit.dtu.dk/fedora/objects/orbit:10350/datastreams/file_3277317/content (accessed 26 November 2013).

- Junghans, A. (2012) 'European FM research agenda', Jensen, P.A. & Balslev Nielsen, S. (Eds.) *Facilities Management Research in the Nordic Countries, Past-Present-Future*. Polytekniks Forlag, Lyngby, 325-339.
- Junghans, A. & Olsson, N. (2012) 'Does facilities management meet the requirements of an academic discipline?', Michell, K., Bowen, P. & Catell, K. (Eds.) *Proceedings of the Joint CIB W70, W92 & TG72 International Conference on Facilities Management, Procurement Systems and Public Private Partnership Delivering Value to the Community, 23-25 January 2012*. Cape Town, South Africa, 115-121.
- Koukiasa, M. (2011) 'Sustainable facilities management within event venues', *Worldwide Hospitality and Tourism Themes* 3:3, 217-228.
- Krishnan, A (2009) "What are academic disciplines? Some observations on the disciplinarily vs. interdisciplinary debate". NCRM Working Paper Series 03/09. University of Southampton: National Centre for Research Methods.
- Lee, S.Y. & Kang, M. (2013) 'Innovation characteristics and intention to adopt sustainable facilities management practices', *Ergonomics* 56:3, 480-491.
- Nielsen, S.B., Jensen, J.O. & Jensen, P.A. (2009) 'Delivering sustainable facilities management in Danish housing estates', in Enric Carrera, J.J. & de Felipe, B.S. (Eds.) *II International Conference on Sustainability Measurement and Modelling: ICSMM, 5-6 November 2009*, p. 135. Available at: http://vbn.aau.dk/files/18719313/S_B_Nielsen_p135.pdf (accessed 26 November 2013).
- Nielsen, S.B., Jensen, P.A. & Jesper, O.J. (2012) 'The strategic facilities management organisation in housing: Implications for sustainable facilities management', *International Journal of Facility Management* 3:1, xx-xx.
- Pitt, M., van Werven, M. & Price, S. (2011) 'The developing use of strategic alliances in facilities management', *Journal of Retail & Leisure Property* 9:5, 380-390.
- Pullen, W.R., van der Voordt, T.J.M. & Hanekamp, J. (2009) 'Input for the 2015 FM Research and Action Agenda' Available at: http://www.cfpb.nl/fileadmin/cfpb/images/publicaties/artikelen/2009/Input_2015_FM_agenda.pdf (accessed 11 November 2013).
- Singh, A. & Elmualim, A. (2012) 'Annual BIFM Sustainability in FM Survey 2012'. Final Report, The British Institute of Facilities Management (BIFM) and University of Reading, Reading, UK.

8.3

EMPLOYING BACK CASTING PRINCIPLES FOR THE FORMATION OF LONG TERM BUILT ASSET MANAGEMENT STRATEGIES – A THEORETICAL APPROACH

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ABSTRACT

Purpose: Facilities managers have traditionally relied on forecasting approaches using the stock condition survey to predict maintenance and refurbishment needs against changing user requirements. However, the authors have previously shown that such an approach, whilst effective for short term planning, is unable to cope with the uncertainty and complex data sets required to develop long term plans (> 10 years), in particular the impact of future climate change (physical and legislative). This paper will present back casting as an alternative approach to support long term built asset management planning.

Background: Back casting has been applied to sustainable transport management, energy planning and community climate change adaptation projects. The process in principle envisions a future state (end-point) set by stakeholders. Alternative ‘paths of approach’ are identified by looking backwards from the future state to the present. Each path is examined in turn to identify interventions (physical and/or operational) required in order for that path to achieve the end-goal. The stakeholder’s review each path and select the most appropriate for achieving the desired (end-point). This path is then integrated into the facilities (built asset) management strategy.

Approach: The researchers worked with various stakeholders as part of an action research team to identify climate change adaptations that may be required to ensure the continued performance of the building and integrate these into a 60 year facilities management plan.

Results: The paper superimposes back casting theory onto the adaptation process and explains how the theory supported long term facilities management planning. The paper also explains how the approach was used to provide confidence for the building owner to invest in the planned refurbishment of their built asset to improve its future performance and sustainability.

Practical implications: The paper demonstrates the application of this approach through a case study example of a newly constructed £75 m educational building. A similar approach could be applied to other building types.

Research limitations: This paper presents a theoretical model which needs to be validated using longitudinal data sets.

Originality/value: This is the first paper to suggest the potential of back casting to inform long term built asset management strategies.

Keywords: Climate change, Back casting, Facilities Management, Built asset management

1 INTRODUCTION

This paper presents an alternative theoretical approach to facilities and built asset management in which back casting is used to identify potential adaptations that may be required to improve a building's resilience to future climate change, specifically increased flooding and overheating. The focus of the project was a new £75m educational building which, at the time of this research project, was at the detailed design stage (RIBA Stage D). The building will occupy a 0.65 hectare brown field site located within a world heritage site. The building will be bounded by transport infrastructure on two sides and residential/commercial building on two sides. The building will have an internal area of 15,267m². The building will house Academic Departments, a University Library and provide a series of shop fronts onto the main street. The building has been designed to achieve BREEAM excellence. The aim of the research project was to examine the potential impact that future climate change could have on the performance of this building in-use and develop a 60 year adaptation strategy to address any potential negative impacts. An action research approach was used in this project.

The impacts that climate change could have on built assets is well documented (Sanders and Phillipson, 2000; Camilleri .et.al, 2001; Liso .et.al, 2003; Levermoore et.al, 2004); as is the suitability of alternative adaptation strategies to address these impacts (Gavin et.al, 2005; Hacker et al, 2005; DCLG, 2010; Tillsona et al 2013). What is less clear from literature is how adaptation strategies can be integrated into long term built asset planning (Desai and Jones, 2010). Desai and Jones (2010) argued that the uncertainty associated with climate change; the long term nature of future climate projections; and the short term operational demands placed on buildings make it difficult for facilities managers to prioritise climate change adaptations over other interventions that have a more immediate benefit. However, failure to address climate change in a timely fashion could render many buildings prematurely obsolete. Desai and Jones further argue that current forecasting tools used by facilities managers to set built asset management plans could exacerbate the problem by restricting the scope of possible long term 'futures' to an extrapolation of current experiences and performance trajectories. Such an approach will limit the inclusion of step change scenarios that may be required to address the impacts that future climate change could have on many buildings.

This paper presents an alternative approach to developing long term 'futures' based on back casting. The paper reviews the theory of back casting against the backdrop of a new £75m educational building. The paper outlines the action research approach that was used to develop a 60 years climate change adaptation strategy for the building and presents a theoretical model by which the learning from the action research project could be applied more generally as a part of the strategic built asset management process. The paper concludes that back casting could provide the theoretical base to support the step change in thinking about built asset management performance that is required to address future climate change. The paper also identifies the need for new life cycle analysis tools to support a back casting approach.

2 STATE OF THE ART

Future studies have been used for policy planning; in depicting economic and market trends; and for setting organisational strategies. In this context Chatterjee and Gordon (2006) identified a ‘futures’ spectrum and described a range of approaches to deal with uncertainty and ambiguity at one end of the spectrum (e.g. behavioural simulations, scenario planning and modelling etc.) and certainty at the other end of the spectrum (e.g. forecasting, exploration etc.). Banister and Stead (2004) and Miola (2008) also examined the role that scenario planning played in future studies and mapped the different types of scenario to different types of futures (Table 1).

Table 1: Future studies and respective scenarios

Future Studies	Questions	Scenario
Probable	What is likely to happen	Precautionary /Predictive scenarios
Possible	What might happen	Explorative/ Projective scenario
Preferable	What we would prefer to happen	Visionary/Normative Prospective scenario

‘Probable’ and ‘Possible’ future studies are described as forecasting approaches which use predictive and exploratory scenarios based on quantitative data generated from surveys, past and current trend monitoring and explanatory modelling to develop views of the future. ‘Preferable’ future studies are described as back casting approaches which use visionary and prospective scenarios based on a mix of quantitative and qualitative data generated through workshops, focus groups and Delphi techniques to develop views of the future. In all cases the future views provide the criteria against which success or failure of alternative solutions can be evaluated.

The term back cast is widely attributed to Robinson (1982, 1990) who defined it as a normative method in which a desired long-term end-point is set and then used as the reference point to ‘look back’ to the current day position to identify the various stages at which actions are required to achieve a successful journey from the current day position to the preferred future position. In a review of back casting Dreborg (1996) concluded that the approach was most applicable to situations where:

- the problem being addressed is complex and a change in the existing trend is required;
- time frames are long and deliberate choice (interventions) need to be made;
- dominant trends are part of problem; and
- the problem scope is wide and externalities are crucial.

The author’s contend that these criteria map well to the problems associated with integrating climate change into future facilities and built asset management decision making models where:

- climate change scenarios are complex and riven with uncertainty;
- facilities and built asset management time scales are long, typically 30-60 years;
- short-term thinking tends to dominate over long-term objectives;

- where potential solutions involve multiple stakeholders and external agencies.

Indeed, these issues are not dissimilar to those addressed in back casting studies that examined energy (Robinson et al, 2011) and sustainability (Miola, 2008) futures. Of particular relevance to this project is Robinson's work (ibid) in which a modified version of back casting, participatory back casting, was used to gain input from a broad range of stakeholders to collectively develop future scenarios. In the current project action research was used to engage a wide range of stakeholders in the development of the future scenarios. Although not designed as part of the original action research model, the process of developing the future scenarios mirrored very closely the 5 stage model suggested by Quist et. al (2006). This is discussed in more detail later in the paper.

- Stage 1: Strategic problem orientation;
- Stage 2: Specification of external variables;
- Stage 3: Construction of future visions or scenarios;
- Stage 4: Back casting: backwards-looking analyses;
- Stage 5: Elaboration and defining follow-up and an action agenda;

Finally, whilst most research studies have treated back casting and forecasting as separate, distinct approaches, Hojer and Mattsson (2000) suggest that they can be combined in situations where forecasting alone suggests the future end-point is unlikely to be reached. In this case back casting provides the futures vision whilst forecasting can be used to quantify the ability of interventions to bring about the desired future. Such an approach emerged as the most suitable model for integrating climate change adaptation into built asset management in the current research project.

3 THEORETICAL APPROACH AND RESEARCH METHODOLOGY

3.1 Theoretical approach

The subject of the research project was a £75m new educational building. As part of the initial design the client requested their Facilities Management department to work with the design team to undertake a review of the potential impact that climate change could have on the building and develop a long term facilities and built asset management strategy to ensure that the building continued to perform at an acceptable level over a 60 year period. Researchers from the University of Greenwich were part of the project team.

3.2 Action Research Process

The action research project commenced in October 2010 and was completed in June 2011. The action research team comprised representatives from the Architects; Building Services Engineers; Structural Engineers; Quantity Surveyors; the Client (represented by the Facilities Management Department); and members of the Sustainable Built Environment Research Group at the University of Greenwich. In addition, specialist input to the project was provided by a climate change expert who developed the climate impact models. The action research team met formally on 4 occasions. Each of these meetings was in the form of a 1 day workshop. Between workshops members of the team worked in small groups to develop, test and refine their inputs. The first meeting established the focus for the project; developed a set of questions for the partners to investigate; agreed procedures for data gathering/analysis; and outlined a set of deliverables for the second meeting, which was mainly concerned with an

assessment of the antecedent climate threats and the identification of future climate change risks.

At the second meeting the action research team received a climate change risk report that identified current and expected risks aligned to the predicted first and second refit of the building (2020 and 2040) and design life (2080). The risk reports were generated using the UKCP09 (median prediction emissions scenarios) to produce likely weather scenarios and associated building impacts on: Internal Comfort & Building Façade; External Comfort; Structural Stability; Infrastructure; Water Supply; Drainage & Flooding; Landscaping; and the Construction Process. Although a wide range of extreme weather events were examined, due to limitations in national data sets the final analysis was limited to issues of thermal performance, where 3.8-4.8°C rise in annual mean temperature above the control period was predicted by 2080 and pluvial flooding, where an increased risk was identified to the basement areas and attenuation tank capacity.

Once the weather data had been presented, the facilities management members of the action research team developed performance specifications, in terms of operational expectations of the building for 2020, 2040 and 2080, and the design members analysed how their design solutions would perform against each specification (Prospective scenarios in Table 1). In particular 4 questions were considered: 1) Would rooms overheat in the future? 2) What will be the impact on the annual energy loads? 3) Can the chiller specification cope with the increased load? 4) How will solar gain change in the future? These analyses were presented to the whole action research team at the third workshop. As this project was solely concerned with the impact of climate change no account was taken of other future scenarios (e.g. economic, political etc.).

The third Workshop examined the design implications of the questions outlined above. The performance specifications provided the 'operational targets' (end-points) from which costed adaptation solutions were 'back-cast' to ensure that the building would meet its targets over its life-cycle. This process identified twenty five adaptation measures which were tagged as 'do now', '2020', '2040' or '2080'. Each adaptation was evaluated against the following principles:

1. Measures that required structural alteration were recommended to be undertaken immediately irrespective of their actual required implementation date.
2. Measures that required changes to system or component capacity were only to be implemented when required but consequential structural and space planning issues were implemented as 1) above.
3. Each measure was considered in terms of its impact on the current design and modifications introduced to facilitate a future retrofit.
4. Those measures that were identified, but for which the UKCP09 weather data provided no firm direction, were assessed on their merits. This particularly applied to the risk of flooding where preparation was undertaken even though the likelihood of future events was uncertain.

At the final workshop each of the detailed adaptations were considered and either adopted or rejected by the client team. Of the 25 detailed adaptations developed through this process, seven were adopted immediately and included in the final detailed design. The remainder

formed part of the future facilities and built asset management plan. The full list of adaptation measures can be seen in Table 2.

Table 2: Adaptation measures and implementation schedule

Risk	Adaptation/ Comment	Implementation			
		Now	2020	2040	2080
Overheating	Alter the current glazing system to allow for openable windows to be easily installed in future			•	•
	Install additional chillers on the roof		•	•	
	Future thermal design modifications should be based on an adaptive comfort model		•	•	•
Overheating and Energy Use	Introduce a 'siesta'. Behavioural adaptations were seen as beneficial and could limit the predicted thermal issues. However it would impact on the usability of the building.		•	•	•
Reduced Heating Load	Replace boilers with an increased number of smaller sized units			•	
Insufficient comfortable external areas	Allow all building users to access the roof areas Introduce shading to external spaces Introduce external water features	•			
Increase in cooling load	Allow for an increase in plant and riser space	•			
Infrastructure failure (electric)	Add access control to the standby generator	•			
Infrastructure failure (gas)	Include for an electric back-up form of heating (GSHP)			•	
	Increase hot water storage			•	
Infrastructure failure (water)	Increase the cold water storage			•	
Infrastructure failure (drainage)	Increase size of Attenuation tank				•
Increase in storm activity	Increase capacity of rainwater pipes & drainage				•
	Increase roof capacity to store rainwater				
	Permanent flood protection measures to basement areas	•			
	Include adaptable door frames for door dams Increase the height of the retaining walls				
Failure of drainage system	Connect drainage system to the BMS	•			
Increase in ground-water level	Provide adequate build-up above the tank to avoid flotation	•			
Increase in water costs	Introduce waterless urinals Add a rainwater recycling system			•	
Waste from refurbishments	Upgrade facade systems with recyclable materials	•			
Insufficient cycle storage spaces	Increase the cycle store capacity	•			

5. DISCUSSION AND PRACTICAL IMPLICATIONS

The approach that emerged from this project used back casting as a primary method for evaluating the future needs of the building and for assessing the possible adaption paths by which the performance of the building (against climate change) could be ensured over a 60 year time span. An action research approach, incorporating a series of brain storming workshops and group consultation was used to develop future climate impact scenarios against which a range of potential adaptations were assessed. From this study a generic 6 stage approach to the application of back casting to facilities and built asset management was developed.

The first task for the action research team was to establish the desired outcome (in terms of building performance criteria) that any adaptation solution would need to satisfy. This process involved establishing the future context within which the building would have to operate. To do this, existing corporate documents were examined and reviewed. These documents included the organisation's mission statement and long term strategic plans. Following a brainstorming session involving all the project stakeholders' a facilities management problem orientation statement was developed. The statement said that any adaptation strategy should seek to ensure that "the performance of the new built facility in terms of its future resilience to climate change, and ability to fulfil mitigation targets, should be achieved without compromising user comfort and future operational demands".

Once the future building expectations had been articulated, specific performance criteria were established against which specific adaptation options could be evaluated. In the case of this project the key criteria were future CO₂ reduction, energy efficiency improvements and resilience of the building to the impacts of flooding (identified as a consequence of increased storm intensity and the inability of the local drainage system to cope with the expected volume of water). Wherever possible quantitative performance targets were set (e.g. future overheating thresholds) against which adaptations to future climate change projections could be evaluated. Where this wasn't possible (e.g. behavioural responses to overheating) qualitative performance targets were set as a guide to future expectations.

Setting the expected 'end-point' or 'target' of future adaptations provided a focus for the development of alternative paths that could be taken to achieve the end-point. This process again involved a brainstorming exercise to establish a range of future paths (technical and operational) that could form the basis of alternative adaptation strategies. As a starting point the team established a business as usual scenario which gave a point of reference for visioning alternative future scenarios by reflecting on shared knowledge of the organisation. Five future scenarios were developed.

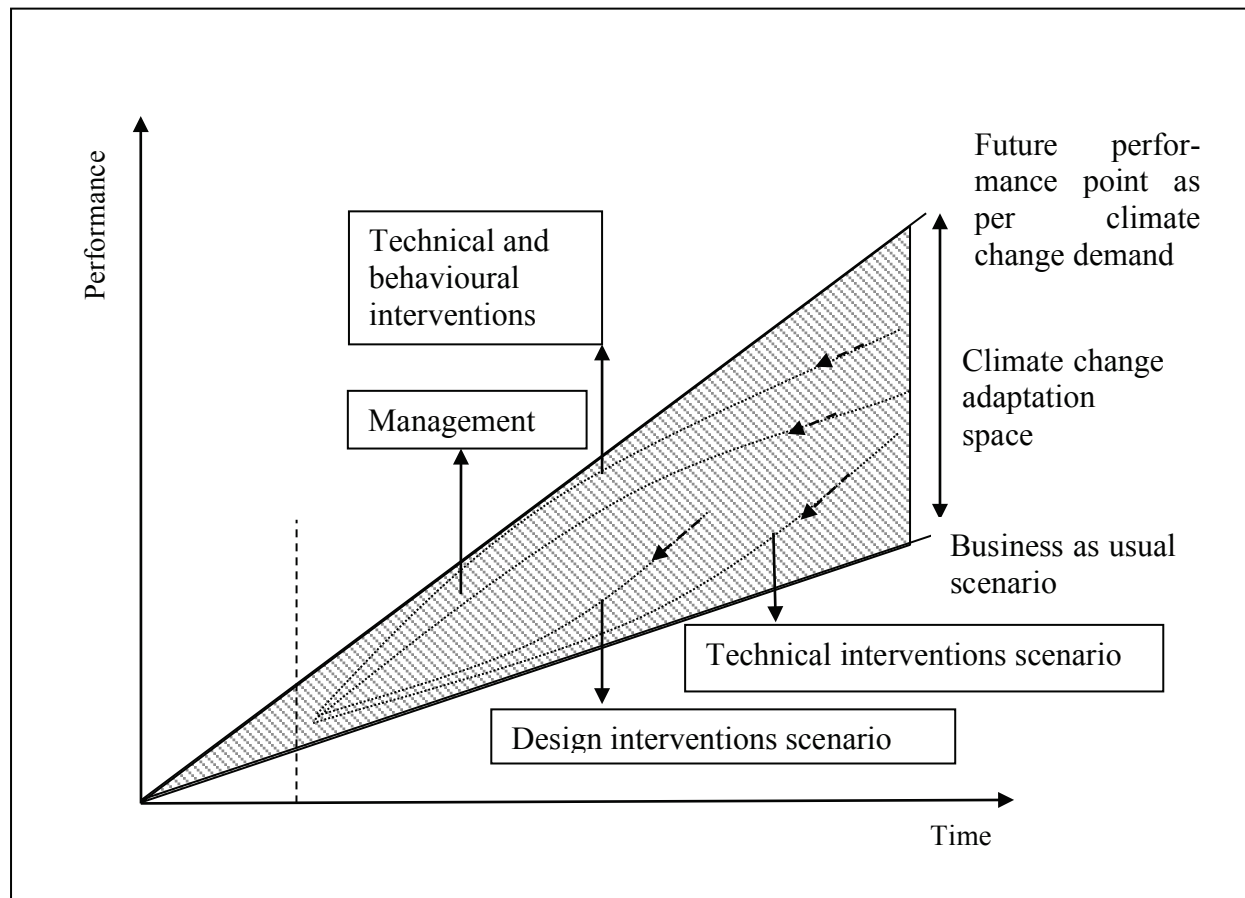
- Scenario1 (business as usual path) – For this base scenario the energy load due to heating and cooling was presumed to increase whilst the energy supply source remained the same (i.e. energy supplied using a mix of gas and electricity). The resulting CO₂ levels would be offset by buying carbon credits to ensure the organisation hit expected UK government targets for their sector. No additional adaptation measures for flooding resilience were considered with cost and disruption of any future flooding

event being dealt with through existing disaster recovery and business continuity plans.

- Scenario 2 (management path) – Considering the UK Government drive for renewable energy, this scenario envisioned new procurement contracts for renewable energy supply. The scenario also envisaged new workplace strategies to encourage energy efficient behaviour (e.g. incentives and acknowledgements for energy efficient departments and employees). A new disaster recovery plan using a flood warning system to trigger a flood management strategy is also envisaged.
- Scenario 3 (design path) – This vision outlined use of landscaping and natural ventilation systems to reduce cooling loads in the event of an increase in overheating in the future. Building users would also be encouraged to make use of external spaces, particularly the roof gardens. The landscape would be designed using SUDS (sustainable urban drainage systems) principles and this would also make the site more resilient to flood events.
- Scenario 4 (technical path) – This scenario assumed a range of technical adaptations would be retrofitted to the building as and when they were needed. The difference between this approach and a traditional refurbishment model is that the building would be designed with specific retrofit upgrades in mind. This would include initial preparatory works being undertaken during the original construction phase to allow subsequent retrofit in the future. Measures for flood resistance such as flood gates are put in place; the electrical sockets are placed above flood level; and the basement would have resilient fixtures and fittings. No services would be placed at basement level and flood kits would be provided for after flood cleaning process.
- Scenario 5 (combined technical/management path) – This scenario outlined the use of a combination of technical (e.g. additional air condition units or portable fans during overheating events) and management (e.g. staff encouraged to adopt a casual dress code and make use of outdoor spaces during breaks) adaptations similar to those described above.

These scenarios are shown graphically in Figure 1. Whilst the scenarios were not developed with back casting in mind they do demonstrate back casting principles. The figure shows the expected performance of the building over time. The dashed line represents the ‘present time’ where the actual performance of the building under a ‘business as usual scenario’ is below the optimum that would be desired (the top line). The assumption in the diagram is that this underperformance is due in part to the current impacts of climate change. The bottom line represents the improvements in performance over time that could be expected from existing facilities and built asset management plans. The top line represents the required performance as derived from the visioning scenarios for the effect of climate change (the desired end-point). The space between the two lines represents the adaptation space that needs to be addressed. The lines within the adaptation space are alternative adaptation pathways that were back cast (the arrows) from the future end-point. Design and technology adaptations are assumed to be lagging solutions; management and behavioural adaptations are assumed to be leading solutions. At this point the model is explanatory and not intended to identify the most appropriate adaptation route for a building.

Figure 1: Explanatory model of the back casting approach



In order to work out the operational and financial feasibility of the scenarios a building simulation modelling exercise was undertaken. Each scenario was considered against 8 principle design criteria: Internal Comfort & Building Façade; External Comfort; Structural Stability; Infrastructure; Water Supply; Drainage & Flooding; Landscaping; and the Construction Process. Each scenario was considered against 2020, 2040 and 2080 time frame. The feasibility studies identified 42 possible adaptations, the majority of which were technical in nature. The fact that technical adaptations dominated discussions was not surprising as the majority of the action research team were engineers and architects who were familiar with undertaking technical assessments. Indeed, the lack of an approach for considering management strategies for climate change adaptation was one of the key findings to emerge from this part of the study.

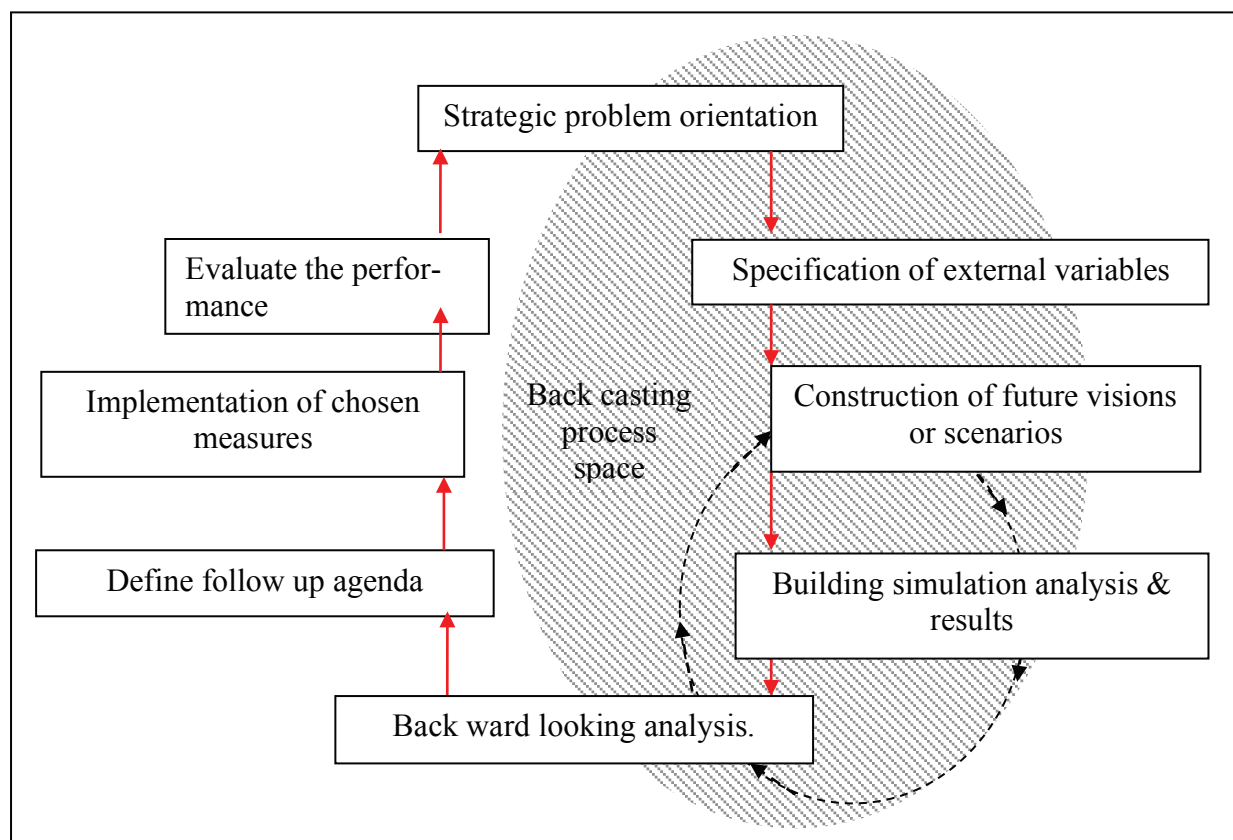
In Phase 5 of the process the facilities management team reviewed the adaptation options to identify when in the building time line each would need to be enacted. The review process included an assessment of the cost and benefits that each adaptation would have on the building's performance. The adaptations generally fell into three categories; immediate implementation of the adaptation solution as part of the original build; implementation of preparatory work as part of the immediate build to allow for a planned future upgrade; or future operational changes to the building. An example of an immediate implementation was the inclusion of a backup generator to run essential services in the event of a flood. Although the building was not currently at risk of flooding, the future flood risk assessment had identified a potential risk to the critical power infrastructure that supplies the building. This risk, whilst

unquantifiable during the project, was nevertheless considered serious enough for the facilities management team to advise the client of the need to build in a contingency against this possibility as part of the initial design solution. An example of preparatory work was to increase the plant and riser space within the building to accommodate future increase in chiller capacity for cooling (circa 2020) and support a change to a modular based boiler installation to allow for a reduction in installed heating capacity as demand reduces from 2040 onwards. Examples of operational changes were adopting a relaxed dress code (staff) and not programming classes for the middle of the day to encourage behavioural adaptations to the thermal environment within the building. The changes were expected from 2020 onwards.

The final stage involved implementing the various adaptations. Those adaptations identified for immediate application, or where preparatory work was required at the design stage to support their later application, were included as changes to the original building design. These changes were estimated to cost the client an additional 0.4% of total project cost. Those adaptations that were required in the future were programmed into the building's long term built asset management plan. The cost of these changes is estimated at 2.2% of total project cost.

An explanatory model outlining the general approach of back casting application to facilities and built asset management is shown in Figure 2.

Figure 2: Back casting approach



6. CONCLUSIONS

This paper outlined a back casting approach which was derived from developing building adaptation plans that address future climate change. The back casting approach emerged from an action research project of a £75m new educational building. Whilst back casting wasn't explicitly addressed in the action research project, subsequent analyses mapped the processes used in the action research project to back casting theory. This analysis confirmed the applicability of the back casting as an alternative to forecasting to develop future visions against which facilities and built asset management adaptations could be evaluated. This said, the adaptation solutions developed through the project tended to be biased towards technical retrofit solutions, which most likely reflected the balance of the action research team and the lack of an accepted approach for quantifying the cost benefit of management strategies for climate change adaptation. This latter point will need to be addressed if the back casting approach to built asset climate change is to be more widely adopted. The authors recommend the development of such tools as part of facilities and built asset management life cycle analysis.

REFERENCES

- Banister, D, and Stead, D. (2004), "The Impact of ICT on Transport", *Transport Reviews*, vol. 24, issue 5, pg. 611-632.
- Camilleri, M., Jaques, R. and Issacs, N. (2001), "Impacts of climate change on building performance in New Zealand", *Building Research Information*, vol. 29, issue 6, pg. 440-450.
- Chatterjee, K., and Gordon, A. (2006), "Planning for an unpredictable future: Transport in Great Britain in 2030". *Transport Policy*, vol 13, pg. 254-264.
- DCLG (2010), "Guidance and standards for drying flood damaged buildings - Signposting current guidance – BD2760", Department of communities and local government (DCLG), UK.
- Desai, A. and Jones, K. (2010), "Examination of existing facilities management approaches to climate change and future directions". *Proceedings of the São Paulo 2010 CIB W070 International Conference*. CIB Proceedings, Department of Construction Engineering, Escola Politécnica, University of São Paulo, São Paul, Brazil, pg. 585-596.
- Dreborg, K. H. (1996), "Essence of Back casting", *Futures*, vol.28, issue 9, pg.813-828.
- Garvin, S., Reid, J. and Scott, M. (2005), "Standards for the repair of buildings following flooding", *Construction industry research and information association (CIRIA)*, UK.
- Hacker, J., Belcher, S. & Connell, R. (2005), "Beating the Heat: keeping UK buildings cool in a warming climate". *UKCIP Briefing Report*. UK Climate Impact Program, Oxford, UK.
- Hoyer, M. and Mattsson, L. (2000), "Historical determinism and back casting in future studies", *Futures*, vol 32, issue 7,pg. 613 -634.
- Levermore, G., Chow, D., Jones, P. and Lister, D. (2004), "Accuracy of modelled extremes of temperature and climate change and its implications for the built environment in the UK", *Technical Report 14*, Tyndall Centre for Climate Change Research, UK.
- Liso, K., Aandahl, G., Eriksen, S. and Alfesén, K. (2003), "Preparing for climate change in Norway's built environment", *Building Research and Information*, vol. 31, issue 3-4, pg. 200-209.
- Miola, A. (2008), "Back casting approach for sustainable mobility", *Joint Research Centre – Institute for Environment and Sustainability*, ISBN 978-92-79-09189-6.

- Robinson, J., (1982), "Energy back casting – A proposed method of policy analysis". *Energy policy*, vol 12, pg. 337-344.
- Robinson, J., (1990), "Futures under glass: a recipe for people who hate to predict", *Futures*, vol 22, issue 8, pp.820-842.
- Robinson, J., Burch, S., Talwar, S., O'shea, M. and Walsh, M. (2011), 'Envisioning sustainability: Recent progress in the use of participatory back casting approaches for sustainability research', *Technological Forecasting & Social Change*, vol 78, issue 5, pg. 756-768.
- Sanders, C., H. and Phillipson, M., C. (2003), "UK adaptation strategy and technical measures: the impacts of climate change on buildings", *Building Research & Information*, vol 31, issue 3-4, pg. 200-221.
- Tillsona, A., Oreszczyna, T. and Palmerbet, J. (2013), "Assessing impacts of summertime overheating – some adaptation strategies", *Building Research & Information*, vol 41, Issue 6, pg.652-661.
- Quist, J. and Vergragt, P. (2006), " Past and future of backcasting: the shift to stakeholder participation and proposal for a methodological framework". *Futures*, vol 38, issue 9, pg. 1027-1045.

8.4

SUSTAINABLE RESILIENCE IN PROPERTY MAINTENANCE: ENCOUNTERING CHANGING WEATHER CONDITIONS

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ABSTRACT

Purpose: The purpose of the study is to develop a methodological approach for project management to integrate sustainability and resilience planning in property maintenance as an incremental strategy for upgrading existing properties to meet new standards for sustainable and climate resilient buildings.

Background: Current maintenance practice is focused on the technical standard of buildings, with little consideration of sustainability and resilience. There is a need to develop tools for incorporating sustainable resilience into maintenance planning.

Approach: The study is primarily theoretical, developing the concept of sustainable resilience for changing weather conditions

Results: The paper suggests a decision support methodology that quantifies sustainable resilience for the analytical stages of property maintenance planning.

Practical Implications: The methodology is generic and expected users are FM organisations with responsibility of property maintenance, and consultants offering property management planning as a service.

Research limitations: The methodology is conceptual and has not been tested. However the concept is to be further developed in dialogue between the authors, the Danish local authority Gentofte Properties and other potential users.

Originality/value: The paper suggests a new methodology to explicitly integrate sustainability and resilience planning in property maintenance planning.

Keywords: Sustainable FM, Climate adaptation, Guideline, Planned maintenance, Property management

1 INTRODUCTION

Every day property managers around the globe plan the maintenance tasks ahead of them, either as part of a periodic inspection and planning process, or as emergent maintenance because an acute problem has occurred. This paper investigates how opportunities for upgrading the existing building stock can be executed in a way that also includes the perspective of sustainable development and climate resilient cities in an integrated way. A building's resilience is a measure of how well a building continues to function during or after an event, and, if the function of the building has been affected, how fast the building can regain its function. Here we are primarily concerned with extreme weather events, but our general framework is applicable to other events, e.g. power failure. Climate resilience has received a significant increase in attention due to predictions that climate change will cause more extreme weather events (Beniston M. et al., 2007).

Climate adaptation and resilience is no longer only an issue at a political level but is also an emerging topic in the FM research literature (e.g. Warren 2010 and Carthey et al., 2009). However, in general, we believe that most of the maintenance and operation strategies in practice do not yet deal with climate change and the sustainability agenda, beyond simple energy savings. Those working with the conditions of current building stock do not consider the risk associated with changing climate.

Typically the maintenance and operation strategies are based on the current condition of the building stock and can be simplified into two types of maintenance: emergent or planned (Flores-Colen I. et al., 2010). The better the building owner knows the condition of his building stock, the easier for him/her it is to plan the cost of maintenance and repairs. In such a portfolio the budget for emergency cost is expected to be small and the planned maintenance cost budgets are distributed through a number of years so the owner is comfortable with his spending. Together with a repair plan, the owner can incorporate the upgrading of the building elements, which will reduce the maintenance or operational cost of the building in the future. However, even a well-managed building portfolio can be disturbed by extreme weather events, which increase emergent maintenance cost and possibly place the owner of the building in financial difficulty. To reduce the risk of unexpected costs, building owners must investigate cost effective options to adapt their properties to possible future environmental changes whose consequences are yet unknown. As Boshier et al., observed, *"Well-designed buildings, properly protected from the hazards associated with climate change, will be easier to sell or let and could also command higher prices. Opportunities are therefore available for organisations to position themselves as market leaders in the climate-related 'future-proofing' of buildings, thereby presenting a means of attracting new customers and gaining a competitive edge."* (Boshier L. et al, 2007).

Numerous methods have been proposed for measuring both resilience and sustainability, separately. Often the investment needed to make a building more resilient or sustainable is not easy to express in monetary terms, which can then be compared with the investment. This is because many of definitions of resilience or sustainability are difficult to measure, and as such provide insufficient information with which to make investment decisions, as most investment decisions are determined by economic models such as return of investment. To address this issue we investigate a method of quantifying the sustainable resilience of buildings, which can be applied in a decision making process of everyday maintenance strategies. In this paper we discuss how risk management tools familiar to some building owners, facility manager, architects, and other decision makers, can be used to quantify resilience, and facili-

tate the decision process for selecting between remedial solutions with varying degrees of sustainability.

The paper has the following structure. In Section 2, we first review previous work on resilience, sustainability, and sustainable resilience. Section 3 then summarizes how risk management can and has been used to quantify resilience. Ultimately we see resilience and risks as two sides of the same coin: the higher the risk, the less resilient a building is. We then discuss how sustainable solutions can be incorporated into the risk framework through the economic concept of externalities. Section 4 provides an illustrative example of how the framework can be used. Finally Section 5 provides a discussion of future work

2 BACKGROUND

Resilience is becoming increasingly used in the context of climate change and adapting built environment. Most resilience studies on climate change have been undertaken by mapping threats such as the increased possibility of flooding, sea level rise or heat-waves (Beniston et al., 2007), (Biesbroek et al., 2010), (Bosher L. et al., 2007), (de Wilde et al., 2012), (Snow et al., 2011), investigating the vulnerability of a system to these threats (Guan 2012), (Camilleri et al., 2001), (Jentsch et al., 2008), or investigating how to increase a capacity to adapt (Lomas 2009).

2.1 Definition of Resilience

We are interested in resilience to extreme weather events, although the framework is applicable to other events as well. Given the possibility of an extreme weather event, e.g. a heat wave, resilience seeks to determine how well a building or system continues to function during and after the event. As such, we broadly follow the definition of Nelson that “*System resilience refers to the amount of change a system can undergo and still retain the same controls on function and structure ...*” (Nelson et al., 2007), although we acknowledge a number of other possible definitions of resilience depending on various perspectives. (Manyena S.B., 2006), (Folke C. et al., 2002), (Bosher L. et al., 2007). (Carpenter S. et al., 2001; Christenson M. et al., 2006; Cole R.J., 1998; Cox R.A et al., 2014), (Holling C.S, 1996), (Pimm 1984)

While such measures are valuable, particularly in the context of understanding the ecology of a region, we believe such measures are of limited value in supporting the process to decide whether remedial action should be taken to improve a building’s resilience. For example, knowing that a building is resilient to average daily temperatures of up to say 30C is useful, but any investment decision must also consider both the cost of failure when daily temperatures exceed 30C and the probability of such weather events occurring. The latter probability is necessary to arrive at an overall expected cost that can be directly used to prioritize investments. Assigning an economic cost to resilience can be handled using well-known risk measures, which are discussed in the next section. However, before doing so, we next discuss sustainability.

2.2 Definition of sustainability

The definition of sustainable development (SD) was defined by Brundtland Commission in 1987 as “development that meets the needs of the present without compromising the ability of future generations”. This definition is often described as triple bottom line, because it considers ecological, economic and social consequences of development. According to this definition the environmental, social and economic needs are defined as equal and “*must deliver*

prosperity, environmental quality and social justice” (Ding G.K.C., 2008). We argue, that the Brundtland definition is very broad, without a clear understanding of the limits of the natural cycle of a limited area. This definition of sustainability is difficult to quantify. To be able to quantify and measure sustainability we view sustainability as “the ability of our own human society to continue indefinitely within natural cycles of the earth” Baxter et al. (2010). By doing that we could identify the natural cycles of the limited geographical area, such as a country, a city, a company, a project or even a building.

As resilience can be quantified using risk analysis, similar the sustainability can be measured by quantifying a building’s impact on environment. However the impact on environment is more difficult to quantify as some of metrics such as different greenhouse gasses (GHG) are quantitative and well defined and can be compared globally, and other impacts such as overall impact on environment can only be quantified qualitative by “awarding points for presence or absence of desirable features” (Cole R.J., 1998). Most of building sustainability assessments tools such as BREEAM, LEED or DGNB etc. are well defined tools for a specific type of building in specific geographical area and taking into account both qualitative and quantitative metrics (Ding G.K.C., 2008). Most of the building assessment tools are based on a scoring system, which is defined and weighted by either (i) all criteria’s are weighted equally, or (ii) weighting coefficients were determined by questionnaire survey of users of the system such as designers, building owners, operators, and can be modified to suite the local conditions.

From the facility managers' perspective there is still missing a method to evaluate smaller refurbishment projects where only one or two components of the building are to be replaced as part of maintenance. In such projects the environmental impact should to be expressed in monetary terms to be able to feed in to the traditional Cost Benefit Analysis (CBA). The CBA is a well-respected tool where everything is converted into monetary terms and decisions are based on highest net value (Ding G.K.C., 2008). As we already discussed, the environmental impacts are not always possible to express in monetary values. We investigate how the environmental impacts can be included in CBA.

2.3 Definition of sustainable resilience

The idea of merging both sustainability as a mitigation option and resilience as the adaptation option has been suggested by (Mills E. et al., 2003), (Bosher L. et al., 2007) and (Camilleri M. et al., 2001), (Folke C. et al., 2002). However, the authors only discussed a need of coupling the sustainability and resilience without suggesting how to quantify them.

3 APPROACH

The study is primary theoretical as it draws on current literature on sustainability and resilience to develop the concept of sustainable resilience. However it builds on the example of property maintenance in the Danish Municipality Gentofte, and illustrates how Gentofte and other property managers can innovate their property maintenance planning practice to meet new political strategic goals of sustainable resilient properties.

Risk and resilience are seen as two sides of the same coin and therefore the developed guideline adopts a risk management approach. (Jones 2012) has a similar approach when suggesting a framework for risk assessment for extreme climate change challenges. The difference between Jones and this paper is primary that we integrate traditional building technical

maintenance not only with extreme climate change risks, but also with the sustainability profile of the building.

This study could be done in a qualitative way to illustrate the line of thinking. But in order to meet the expressed need of measuring and quantifying engineering solutions to demonstrate a value and to allow multi-criteria comparisons of alternative solutions and total cost/value evaluations, we aim for quantifications of each indicator. We also assume an economist's perspective that facility managers are rational and base decisions on economic criteria, i.e. facility managers are asked to create as much value as possible out of a given budget.

The paper presents work in progress and is therefore not fully developed in terms of suggesting specific measures for sustainable resilience.

3.1. Quantification of resilience

In summary the resilience can be measured by (i) defining most significant indicators, or (ii) using risk analysis. The risk (R) is defined as the expected consequences associated with a given activity (Faber M.H., 2012). Risk can be described by a function of probability (P_i) of an event, i , occurring, together with the consequence (C_i). If there are n possible events, then the risk is defined as

$$R = \sum_{i=1}^n P_i * C_i$$

From the facilities management point of view there are several advantages for using risk assessment for quantification of resilience:

- a. To be able to calculate the risk assessment the object or system whose resilience we are investigating must be well defined: resilience of what, and resilience to what. Thus, to quantify the resilience of a building, we need to split the building as a system into different problem areas: for example if we are investigating the resilience to overheating we are only looking into the indoor temperatures and not other parameters such as degradation of the external materials.
- b. By calculating the risk of failure it is possible to express the failure in monetary terms. How much it will cost if the system will fail and how much it will cost to prevent that failure.

However the disadvantage of only taking the risk assessment into account is that the overall resilience of the building will be difficult to assess and the environmental impact of the proposed solution is not evaluated.

To be able to include the environmental impact of the solution we also require to look at the sustainability assessment methods that are described below.

3.2 Quantification of sustainability

The quantification of sustainability of buildings can be measured by:

- (i) Different sustainability indicators covering all 3 aspects of sustainability (ecological, economical and social) and are usually defined from project to project
- (ii) Environmental assessment tools, which are based on the awarded points, and are weighted by the overall impact on buildings and is often a 5 level system, where 5 is the most desirable environmental performance of the building. The advantage of such a system is that the evaluation of the building's environmental performance becomes

more comparable within the same scheme and within the regions. The disadvantage is that it does not take economic cost nor resilience into consideration (at least not directly)

- (iii) Sustainability index where different alternative solutions can be calculated and compared to each other by including not only the economic cost of a solution but also the Benefit Cost Ratio (BCR), Energy Consumption (EC), External Benefits (EB) and Environmental Impact (EI). This has the advantage of considering economics but not resilience.

3.3 Quantification of sustainable resilience

The first attempt to quantify both the sustainability and resilience was proposed by Camilleri using Climate Change Sustainability Index (CCSI), (Camilleri M. et al., 2001). The author proposed to establish a scoring system rating from -2 to +5, where the scores are given based on Annual Exceedence Probability (AEP).

- (iv) Climate change sustainability index, which rates a building's adaptation performance by using the probability of return of extreme event, which will affect the performance of the building. The method proposed ranking a building from -2 to 5 (where 0 represents no risk at present, but the risk is already occurring in the adjacent properties).

4 RESULTS

The focus of the paper is how to quantify sustainable resilience as input to maintenance planning. In the following we use risk and incorporate additional costs to non-sustainable solutions. These costs are often referred to as externalities within economics such as: carbon costs, water consumption, public relations etc. These costs allow a return on investment (ROI) to be calculated for both resilient and sustainable resilient solutions. The general approach is to define risk and introduce the basic concepts, e.g. probability of an event and cost of event and compare it with the expected cost of the maintenance project.

To illustrate the methodology we investigate how resilient a historical naturally ventilated building is to changing weather conditions. We restrict our investigation to only one changing parameter – external temperature and investigate the building's resilience, i.e. ability to maintain its function during the extreme high temperatures. We consider the spatial area of Denmark and the time periods of current climate, 2050 and 2100.

4.1 A 6 step approach to measuring sustainable resilience:

Given (i) a building and (ii) a disturbance, e.g. temperature

1. Determine the resilience of the building to temperature, i.e. at what temperature will the building's functions be compromised?
2. Determine the cost associated with the loss of building functionality.
3. Determine the probability of the event/disturbance occurring.
4. Apply risk analysis to determine the expected cost associated with the current resilience of the building, (existing conditions).
5. Determine cost of remedial solutions as well as period when the solution is required
6. Apply cost benefit analysis to select (or not) a solution

To incorporate sustainability, step 5 is expanded as following;

- a) Determine capital and operating costs, as before
- b) Determine direct/indirect ecological costs, e.g. carbon tax, etc.

- c) Determine intangible costs to say, reputation
- d) Add (a)-(c) to determine total cost, then go to Step 6

The steps for investigating sustainable resilience, described above, are used to illustrate the example below. The example investigates the resilience of a naturally ventilated building to heat waves in Denmark, as an illustration of the principles of the method.

Step 1 Determine the resilience of the building to temperature

The resilience of building stock depends on the type of extreme weather events, which will have different consequences. Increased temperature will reduce heating demand, but increase cooling demand and will increase the risk for overheating (Christenson et al. 2006) (Jentsch et al. 2008).

In the context of the risk of overheating in a naturally ventilated building, we define the Limit State Function (LST) as the event when the naturally ventilated building (i) fails to provide a comfortable thermal environment, which can result in loss of productivity, (ii) must be closed due to overheating, and (iii) becomes a risk to human life.

Table 1: The threshold for different LSF in naturally ventilated building

Stages of failure	Internal temperature °C
No impact (G_0)	$21 < t < 25$
Loss of productivity (G_1)	$25 < t < 30$
Loss of function (G_2)	$30 < t < 32$
Risk of mortality (G_3)	$32 < t$

Step 2 Determine the cost associated with the loss of building functionality

The cost associated with the loss of buildings function will be different for different stages of failure G_1 , G_2 , G_3 . The risk of mortality G_3 will not be discussed further as the building will be closed before the risk will occur. Therefore the risk of loss of function G_2 will be expressed as the loss of function during periods where the external temperature exceeds 32°C . The cost of productivity is most relevant for this case and is discussed in detail below.

A review of the literature investigating the relationship between indoor temperature and productivity is provided by (Seppanen et al. 2004), who observed a strong correlation between temperature (t) and productivity when the temperature is above or below the comfort zone ($21\text{--}25^\circ\text{C}$).

Based on the analysis the author develops a model to calculate productivity loss based on internal temperature, which we have adapted to calculate the productivity loss in our building. As we assume that our case study building is an office, we calculate productivity loss L , measured as a percentage and expressed by

$$L = 2 * t - 50, \quad 25^\circ\text{C} < t < 32^\circ\text{C}$$

$$L = 0, \quad 21^\circ\text{C} < t < 25^\circ\text{C} \quad (2)$$

The loss of productivity or function depends on the building. As our case study is an office we calculate the loss of productivity and function based on salaries of employees.

The cost of an employee is based on the assumptions that (i) the annual salary of an employee is 350.000 DKK, (ii) the salary overhead is 2 and (iii) the number of working hours in a year is 2500. Then, the hourly cost per employee is

Hourly Cost per employee = $350.000 \cdot 2 / 2500 = 350 \text{kr}$.

We assume that the cost of loss in productivity C_i can be calculated as following:

$$C_i = \sum_{i=25}^{32} N_e * C_{he} * N_{di} * L_i \quad (3)$$

where i is a temperature from 25...32°C

N_e - number of employees

C_{he} -hourly cost of employee in Dkr

N_{di} - number of hours between i and $i+1$.

L_i – productivity loss of employee for a threshold i in %

Similar, we can calculate the cost of loss of function when the building will be required to be shut down (G_2), and the cost of mortality of the occupants (G_3).

Other factors such as high humidity, which could influence the productivity of the occupants, can be included. However, in this example we restrict ourselves only to the temperature change.

Step 3 Determine the probability of the event/disturbance occurring

The resilience of a building to, for example heat waves, depends on a building's physical properties (location, orientation, building physics and ventilation type), the function of the building, and the climate in the particular location. To define the resilience for the particular building to a particular risk, in this case overheating, the resilience was investigated by applying a dynamic simulation for a model of the building first with a current weather file.

To investigate the building's performance for the future periods 2050 and 2100 we use a simple method to create a future weather file using annual change, based on (Cox R.A et al., 2014) where 5 future scenarios are created: one for 2050 and four for 2100. Then we simulate the building with these different future scenarios to determine the number of hours above the thresholds.

The predicted annual change for these 5 scenarios has been calculated by the Danish Meteorological Institute (DMI) (Olsen M. et al., 2012) and based on IPCC SER scenarios (IPCC, 2011). The report uses a set of 13 regional models with different global circulation models to calculate the average annual and seasonal temperature change for IPCC scenarios A1B, A2 and B2 for the years from 2050 to 2100.

Table 2: Probability of increased temperature for current and future weather

	Current DRY	A1B 2050	A1B 2100	A2 2100	B2 2100	E2 2100
ΔT °C	0	1.32	2.9	3.2	2.5	2
Probability	100	90%	25%	25%	25%	25%

Step 4 Apply risk analysis to determine the expected cost associated with the current resilience

The expected costs can be calculated on the basis of the cost of building new, but recent extreme weather events are providing new statistical data about costs in cases of e.g. storms and flooding. We expect that in the future there will be a more developed basis for estimating expected cost.

Step 5 Determine cost of remedial solutions

The remedial solution is the solution that the property owner suggest based on current practices which focus on the technical standard of the building.

To incorporate sustainability, step 5 is expanded as following;

- Determine capital and operating costs, as before
- Determine direct/indirect ecological costs, e.g. carbon tax, etc
- Determine intangible costs to say, reputation
- Add (a)-(c) to determine total cost, then go to Step 6

Step 6 Apply cost benefit analysis to select (or not) a solution

The last step of the evaluation is to compare alternative solutions in a cost benefit analysis based on a set of indicator which are chosen based on the organisation policy, a building standard (BEAM, LEED etc.) or both.

Table 3: Comparison total cost for of different remedial solutions

Solution	Current conditions	Remedial solution A	Remedial solution B	Remedial solution C
Capital and operating costs				
Direct/indirect costs				
Intangible costs				
Total cost				

5 DISCUSSION AND CONCLUSION

The aim of the paper is to suggest a methodology that can measure the sustainable resilience of specific maintenance project, and to form a basis for evaluating if a specific solution (a maintenance project) is making the building more or less resilience to existing extremes and future extremes, i.e. how the proposed solution is more or less sustainable now and in the future.

We have suggested a 6 step approach to measure sustainable resilience to respond to a need for quantifying resilience and sustainability for maintenance planning. Our perspective is to link maintenance planning done by to FM organisation to meet the political agendas of resili-

ent, sustainable and well maintained cities in the way property management is executed. To some extent this can be done in a qualitative way, but in order to become more mainstream we have investigated how sustainable resilience can be expressed quantitatively, i.e. in monetary terms, to be able to be easily incorporated within the decision making process.

The paper reports work in progress and future studies have to be made to test the methodology and to co-develop it with property owners like Gentofte Property. However, the paper outlines the idea of our approach and supplements other studies (Jones 2012 and Jones et al 2013).

The 6 steps are explained but the first four steps are described more thoroughly than the last two. In the final version all 6 steps should be explained with same emphasis and tested. Currently there is a lack of data and agreed guidelines for quantifying sustainable resilience. However we expect that much more information will be available in the next few years due to current research and practice experiments.

ACKNOWLEDGEMENTS

Thank you to Stine Tharhan, Inge Sørensen and their colleagues from Gentofte Property for financial and inspirational support of the research presented in this paper.

REFERENCES

- Baxter, K. et al., A. B. (2010). *Sustainability Primer*.
- Beniston M. et al, S. D. (2007). Future extreme events in European climate: an exploration of regional climate model projections. *Climatic Change* , 81:71–95.
- Biesbroek G.R. et al., R. G. (2010). Europe adapts to climate change: Comparing National Adaptation Strategies. *Global Environmental Change journal* , 440–450.
- Bosher L. et al., C. P. (2007). *Realising a resilient and sustainable built environment: towards a strategic agenda for the United Kingdom*. Loughborough University. Buildings and Civil Engineering.
- Camilleri M. et al., J. R. (2001). Impacts of climate change on building performance in New Zealand. *Building Research & Information* , 29:6, 440-450.
- Carpenter S. et al., W. B. (2001). From Metaphor to Measurement: Resilience of What to What? *Ecosystems* , 4, 765–781.
- Christenson M. et al., M. H. (2006). Climate warming impact on degree-days and building energy demand in Switzerland. *Energy Conversion and Management* , 47, 671–686.
- Cole R.J. (1998). Emerging trends in building environmental assessment methods. *Building Research and Information* , 26 (1), 3-16.
- Coley, d. W. (2012, July). the implication of a changing climate for buildings. *Building and Environment* .
- Cox R.A et al., D. M. (2014). *Simple future weather files for estimating heating and cooling demand*. Buildings and Environment.
- de Wilde P. et al., W. (2011). Towards probabilistic performance metrics for climate change impact studies. *Energy and Buildings* , 3013-3018.
- Ding G.K.C. (2008). Sustainable construction—The role of environmental assessment tools. *Journal of Environmental Management* , 86, 451–464.
- Eames M. et al., K. T. (2012). A comparison of future weather created from morphed observed weather and created by a weather generator. *Building and Environment* , 252-264.
- Faber M.H. (2012). *Engineering Decisions Under Uncertainty*. Topics in Safety, Risk, Reliability and Quality Volume 18, 2012, pp 1-7.

- Flores-Colin, J., F.-C. I. (2010). *A systematic approach for maintenance budgeting of buildings façades based on predictive and preventive strategies*. Construction and Building Materials.
- Folke C. et al., C. S. (2002). Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. *31*.
- Guan L. (2012). Energy use, indoor temperature and possible adaptation strategies for air-conditioned office buildings in face of global warming. *Building and Environment* , 8-19.
- Holling C.S. (1996). Engineering Resilience versus Ecological Resilience. In A. C. Gunderson S.H., *Foundations of ecological resilience*. Engineering within ecological constraints.
- Hubler M. et al., K. G. (2008). *Cost of climate change. The effect of rising temperatures on health and productivity in Germany*. Ecological Economics.
- Huijbregts Z. et al., K. M. (2012). A proposed method to assess the damage risk of future climate change to museum objects in historic buildings. *Building and Environment* , 43-56.
- IPCC. (2011). *Summary for Policymakers: IPCC special report on renewable energy sources and climate mitigation*. Cambridge: Cambridge University Press .
- Jentsch M.J. et al., B. A. (2008). Climate Change future proofing of buildings - Generation and assessment of building simulation weather files. *Energy and Buildings* , 40, 2148-2168.
- Lomas K.J. (2009). Resilience of naturally ventilated buildings to climate change: Advanced natural ventilation and hospital wards. *Energy and Buildings* .
- Manyena S.B. (2006). The concept of resilience revisited. *Disasters* , 30 (4), 433-450.
- Mills E. (2003). Climate change, insurance and the buildings sector: technological synergisms between adaptation and mitigation. *Building Research & Information* , 257-277.
- Nelson D.R. et al., A. W. (2007). Adaptation to Environmental Change: Contributions of a Resilience Framework. *Annual Review of Environment and Resources* , 32, 395-412.
- Nik V.M & Kalagasidis A.S. (2013). Impact study of the Climate Change on the energy performance of building stock in Stockholm considering four climate uncertainties. *Building and Environment* , 291-304.
- Olsen M. et al., T. C. (2012). *Fremtidige klimaforandringer i Danmark*. DMI. DMI.
- Pimm S.L. (1984). The complexity and stability of ecosystems. *Nature* , 307.
- Seppanen O. et al., F. W. (2004). *Control of temperature for health and productivity in offices*. Lawrence Berkeley National Laboratory.
- Snow M. & Prasad, D. (2011). Climate Change Adaptation for Building Designers: An Introduction.
- Warren C.M.J. The facilities manager preparing for climate change related disaster . *Facilities* , 28 (11/12), 502-5013.

CHAPTER 9

USABILITY AND LEARNING ENVIRONMENTS

9.1

User Experience in an Academic Coworking Place: The Case of Aalto University's Design Factory

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9.1

USER EXPERIENCE IN AN ACADEMIC COWORKING PLACE: THE CASE OF AALTO UNIVERSITY'S DESIGN FACTORY

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ABSTRACT

Purpose: The purpose of this paper was to identify the element of user experience that the Aalto University Design Factory building should support, why and with which spatial solutions. Aalto University Design Factory is an innovation hub type for a coworking place located in Aalto University's Otaniemi Campus area (Espoo, Finland).

Background: The function of academic environments is transforming. Formal learning environments are being accompanied by mix of coworking spaces that facilitate informal learning and collaboration. A user experience-centred approach can provide concrete solutions that allow the workplace planners and managers to meet today's educational needs.

Approach: This aim was achieved using mixed-method research consisting of a digital survey answered by 101 respondents, including students, staff members, researchers, visitors and start-up entrepreneurs. The 6T-model was adapted for the survey to capture the user's experience of places. Based on the results, 15 in-depth thematic interviews were completed with the participation of members of the distinct user groups. A thematic analysis was used to analyse the interview data.

Results: The results describe the six elements of user experience that the ADF buildings should support by highlighting the reasoning behind each element's importance and by introducing spatial solutions and services that support these issues.

Practical implications: In practice, the findings of this research can be applied by facility and workplace practitioners when developing attractive coworking spaces.

Research limitations: To increase the level of generalisation, the results should be investigated in other coworking spaces and by separating the distinct user groups.

Originality/value: Today, coworking spaces seems to be the subject of increasing academic discussion. Thus, this research supports the latest usability research trends in that context by focusing on user experiences.

Keywords: Usability, User experience, Coworking space, Academic learning environment

1 INTRODUCTION

The core skills required in today's economy are believed to include creativity, interdisciplinary thinking, problem solving and the ability to collaborate with others (Bilandzic & Foth, 2013). Education and its environments should support the acquisition of these qualities to educate successful future workers. Investigating the viewpoints of the users of academic environments, including both students and staff, can help meet this challenge.

To improve their performance, academic institutions need to evaluate users' experiences with their facilities and services. The post-occupancy evaluation method introduced by Preiser et al. (1988) is the best-known method for evaluating buildings. However, most satisfaction studies focus on the building, rather than on users' experiences and primary processes. There have been calls for methods for understanding the experiences and behavioural aspects (Alexander, 2008; Inalhan, 2009) of campus facilities' main users, such as the students and staff.

The widely applied ISO 9241-11 standard defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specific context of use" (ISO, 1998). Lately, a redefinition has been suggested that substitutes 'experience' for 'satisfaction' (Alexander, 2010). Therefore, user experience is considered one of the main concepts in the development of learning and working environments and in their usability (Lindahl et al., 2010; Thomas, 2012).

Hence, this study investigated users' experience of the learning environment in the context of academic coworking spaces with an aim of identifying development possibilities and solutions. This aim was achieved via the following research questions: (1) What are the most essential elements of user experience that the Aalto Design Factory (ADF) building should support and why, and (2) Through which spatial solutions and services can these elements be supported?

ADF is a multi-user academic innovation hub type of coworking place situated in the Otaniemi Campus area (Espoo, Finland). It has been described as a space for multidisciplinary innovation (Himanen et al., 2011). ADF has functioned as a cross-disciplinary project of Aalto University since 2008. ADF is located in a late 1950s building of approximately 4,000 m² (gross floor area). It is estimated that 500 interdisciplinary students, 31 ADF staff members, 20 teachers and professors, 5 research groups and 4 companies participated in study activities during the 2011-2012 academic year (ADF, 2012).

This paper is divided into four chapters. After the introduction, the state of the art is presented and the methodology is explained. The results are then discussed. The final chapter consists of a discussion about the practical implications of the results, the study's limitations and future research possibilities.

2 STATE OF THE ART

Learning can take place in both formal and informal settings (McLaughlin & Faulker, 2012). Informal learning relates to learning from other people during social interaction and in less-formal learning environments (Eraut, 2004). The significance of social and collaborative learning has been emphasised in recent learning space discussions (McLaughlin & Faulker, 2012). Matthews et al. (2011) suggest that physical learning environments should include

purpose-built informal social learning spaces to enhance the student experience and strengthen student engagement. These spaces should be flexible in a sense of adaptability to both individual and collaborative work and should have a strong emphasis on social learning and advanced technology (McLaughlin & Faulker, 2012). Informal learning environments have been referred to in previous literature using many names, such as creative spaces (Jankowska & Atlay, 2008), third-space learning environments (McLaughlin & Faulker, 2012) and coworking spaces (Bilandzic & Foth, 2013, Lumley, 2013).

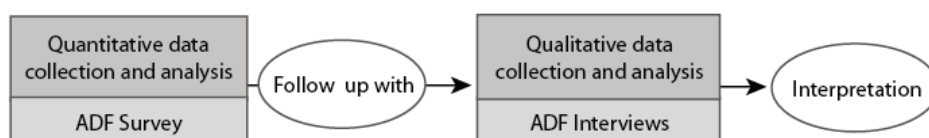
Coworking refers to the co-localisation of group of people with different backgrounds to the same work environment (see, e.g., Spinuzzi, 2013; Parrino, 2013). The spaces and tools are at least to some extent shared among the users (see, e.g., Bostman & Rogers, 2010; Huwart et al., 2012). Some of the coworking spaces emphasise certain values as a base of their function, and Olma (2012) argues that this values-based orientation distinguishes coworking spaces from traditional office environments. These values are collaboration, openness, community, accessibility and sustainability (see, e.g., Bates, 2006; DeGuzman & Tang, 2011; Olma, 2012). Thus, in addition to sharing a physical workplace, coworking can also include activities that enhance collaboration and community building (Parrino, 2013). Consequently, coworking is seen as social working with an emphasis on interaction with other workers (Spinuzzi, 2012). Some coworking spaces are staffed by a host (or community coordinator, coworking space manager or community manager) (Bates, 2006; Huwart et al., 2012) who works to sustain and develop the community.

It has been claimed that students would benefit greatly from becoming more entrepreneurial in their thinking (Lumley, 2013). This change in thinking can happen in innovation hub-type academic coworking spaces, which represent the academic version of creative industry business incubators that enhances early sector development by combining aspects of the olds artists' studio spaces with the serviced office space model (Montgomery, 2007). The collaborative aspects are essential. A study about university campus incubators showed that incubation occurs via a co-production process and depends on the voluntary and active participation of the customer firms or users and on the quality of human relationships (Ahmad & Ingle, 2011).

3 METHODOLOGY

The mixed-methods approach was used in this investigation. The mixed-methods approach is defined as “the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study” (Johnson & Onwuegbuzie, 2004, p. 17). More specifically, the study implemented the explanatory sequential design process of mixed method research (Creswell et al., 2011). The research process consisted of two phases, as shown in Figure 1.

Figure 1: The design of the research process (adapted from Creswell et al., 2011, p.69)



The aim of the ADF survey was to understand the elements of user experience that the ADF building should support. An experience-based usability framework categorised six different dimensions. The so-called 6T model was applied as a framework for the predicate questions to capture the intangible elements of user experience of places. This experience-based usability framework was developed based on customer experience design practices (Diller et al., 2006) and has been applied in different user experience-centred spaces and urban environment research and development situations (see Kojo et al., 2011; Kojo et al., 2013; Tähtinen et al., forthcoming). The model was developed through abductive reasoning. The first version of the model was developed in Finnish and was followed by two English versions. The earlier English version was reported by Nenonen and Kojo (2013); subsequently, the model was further advanced by Tähtinen et al. (forthcoming).

The aim of the experience-based usability framework 6T model is to integrate the different user experience elements of a place into one holistic model that consists of six dimensions: tune, tempo, task, tie, tale and theme. These overlapping dimensions provide a framework for structuring the user's holistic, intangible experience of a place. "Tune" refers to a place's atmosphere, which is created through the sensory environment and cognitive symbols. "Tempo" relates to time and includes such issues as the place's rhythm and its use and sense of time. "Task" relates to functional issues, such as how the users can accomplish their tasks in the place. "Tie" relates to usability matters, such as learnability and ease of use. "Tale" expresses the narrative of the place, such as the continuity and consistency of its story and the visibility of history in the environment. Finally, "theme" relates to the importance and meaning of the place to its users and refers to such topics as support of users' identity and values (Nenonen & Kojo, 2013; Tähtinen et al., forthcoming). The 6T model for capturing the user experience of places is presented in Table 1.

Table 1: The 6T model for capturing the user experience of places
(adapted from Nenonen & Kojo, 2013; Tähtinen et al., forthcoming)

T-concept	Area of concern	Topics
Tune	Atmosphere	Sensory environment and cognitive symbols
Tempo	Time	Use of time, sense of time and rhythm, history
Task	Functionality	Modifiability and support of activities and performance
Tie	Familiarity	Learnability and ease of use, memorability
Tale	Story	Continuity and consistency of the story and narrative, visibility of history
Theme	Meaning	Support of users' identity and values

The survey took place in March-May 2012. It included eight background questions and six predicate questions addressing the necessary user experiences of the building. Each of the predicate questions included 6 claims based on the aforementioned framework, consisting of 36 claims altogether (presented in Appendix 1). The respondents were asked to rate these claims on a one to five response scale (very unimportant – very important) regarding the importance that the ADF building addresses the claim. Altogether, 101 respondents participated in the survey; 41 were students, and 43 were staff members including ADF staff members, researchers, and teachers. Participants from the other user groups were also involved, including visitors (13), and start-up entrepreneurs (4) who had offices in the ADF.

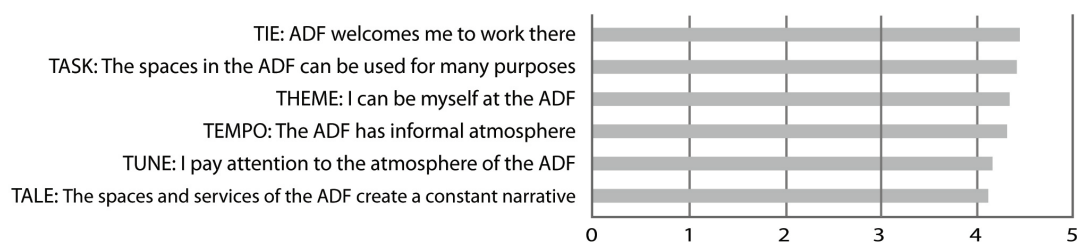
The survey was followed by interviews, with an aim to understand why the elements of user experience that were reported in the survey study were considered important and by which spatial solutions they could be supported. Fifteen of the survey participants participated in recorded and focused (or semi-structured) interviews that were approximately 30 minutes long. The interviewees consisted of 8 staff representatives, 4 students and 3 start-up entrepreneurs. The focused interview is a qualitative research method. It consists of a sequence of themes and questions that are covered during the interview while retaining openness to changes in the sequence and form of the questions. This format enables the interviewer to follow up on the answers given and the stories told by the interviewees (Kvale, 1996, p. 124). The interviews took place in April-June 2012. During the interviews, the highest rated theme was discussed in terms of its importance to the interviewee and which spatial solutions could be used to support it. The interview data were analysed using thematic analysis, “a method for identifying, analysing and reporting patterns within data.”

4 RESULTS

4.1 Most important elements of user experience

Based on the survey results, the elements of user experience users felt the ADF building should support can be seen in Figure 2, which shows the mean values of the highest-rated user experience claims of the ADF survey. All claims and their mean response values are shown in Appendix 1. The top rated claims were related to tie (4.4) and task (4.4), indicating that the spaces in the ADF building should be welcoming and usable for many purposes. The next most important claims were related to theme (4.3) and tempo (4.3), indicating that the building should allow its users to be themselves when using it and should have an informal atmosphere. The fifth rated claim was related to tune (4.2), indicating that the users pay particular attention to the vibe or feeling of the place more than to other sensory stimuli. The final claim was related to tale (4.1), showing that the ADF building’s users consider it important that the activities taking place in the building are visible to them.

Figure 2: Elements of user experience that the ADF building should support



4.2 Elements of the ADF users’ experience

Based on the interview analysis, the user experience elements that the ADF building should support are described in the following chapters in terms of why they are considered important. Additionally, examples of supporting spatial solutions and services are provided.

Sense of a welcoming place

A place with a welcoming atmosphere may be attractive, as one student stated: “If it was a closed group, it would be good for the people inside, but outsiders with new ideas would not

come.” A staff member described the change in visitors’ behaviours as follows: “Suited men with stiff body language... often, when we walk around the building, it changes... they ask many more questions and even laugh intermittently, and their body language becomes more relaxed.” It was generally reported that it is the people who create the welcoming feeling and not the physical space. As an entrepreneur described, “It emerges from the operating model that you say hello to people, speak to strangers and dare to encounter others.”

However, spatial solutions and services were also seen to have an effect on the welcoming atmosphere. A researcher noted the importance of knowing that the place is accessible every day at all hours even before one’s first visit. Users who do not have an access key can enter by ringing the doorbell. A staff member commented on this convention as follows: “When you come here, you have to ring the doorbell, and then somebody answers... you can tell if this person is smiling or not even just by hearing the voice.” The importance of this situation was further stated: “It’s a little detail that creates the first impression of what the whole experience is going to be like.” Regarding the interior of the ADF, an entrepreneur valued the fact that “When you enter the main door, you arrive right in the middle of action.” A staff member considered the suitable layout for the lobby space: “There is furniture that communicates that you can sit and spend more than two minutes there... not just wait for the meeting to start.” According to that staff member, a solution would be providing “furnishing that is comfortable... for example, what is used in cafeteria-like environments.” The freedom to use the spaces and their availability via a general-use policy create a welcoming atmosphere. In addition to reservable spaces, there are many facilities that can be used without a reservation. As an entrepreneur emphasised, “The basis is that if the space is not reserved, you can use it”.

Possibilities for multi-use of the building and spaces

According to the survey results, multi-use means the flexibility of the facilities to adapt to and support users’ distinct activities. Multi-use was seen to apply at both the building and space levels. A student described multi-use as follows: “There are several different spaces under the same roof that can be used for more than one use purpose”; for example, “You can have a lecture and do the related teamwork in the same space, and you can also go to an individual work space inside the same building and then come back.” The reasons given for the importance of multi-use facilities were diverse. A researcher noted that such facilities “suggest alternative ways of doing things,” and student said that they “help to expect unexpected.” More practical reasons for providing multi-use spaces related to the possibility of finding spaces that suit the users’ current activity and mood, as an entrepreneur said, or increasing the use rate, as some of the staff members explained.

A student imagined the different space types of ADF as follows: “You have rooms for individual work, a very informal beanbag chair but also more formal teamwork and meeting spaces, many workshops and labs as well as bigger multi-use spaces.” A staff member described the use of these bigger spaces by saying that “you can arrange lectures, workshops, parties, exhibitions, dinners or anything else.” The results show that the furniture in the multi-use spaces should be easy to move. This can be accomplished by providing light furniture or furniture with wheels. A staff member emphasised that the facilities’ use policy may have an effect on its flexibility: “If the metal workshop closes its doors at 4 pm, its multi-use ends then.” In contrast, as a student noted, the building’s 24/7 availability policy makes it more flexible to use. A researcher praised the absence of certain rules that allow sticking notes to the walls, for example.

Permission to be oneself

Although most of the interviewees mentioned that they feel as if they can be themselves all the time, the subject prompted discussion. The possibility of being oneself was generally described as not needing to act according to a strict behavioural model. As an entrepreneur put it, "You come and go as you will without needing to dress or talk in a certain way." The benefits of being oneself were considered to relate to enhanced productivity and learning. It "allows you to work on your potential," as a staff member explained. Another staff member emphasised that "You dare to ask stupid questions... you cannot learn without asking questions." Another staff member said, "If you try with a negative attitude and then fail ... maybe that's the last time that you will ever do it again."

The opportunity to be oneself was seen as something that is created more by the people than the space or services. As a staff member put it, "People are open, kind to each other and passionate," or equal to each other, as another staff member noted. The role of the managers is central because they provide an example to others of how to act, participate or even dress, as one staff member noted. Some spatial solutions and services were mentioned, such as the 24/7 opening times and spaces that enable informal interaction. The Kafis (the common kitchen-cafeteria at the ADF) was seen as an example of that type of place. Some users saw relaxing spaces as especially suitable. A researcher explained, "No traditional office look ... you can do the same kind of things as at home, for instance, have coffee and sit on the sofa for a while... and be in your socks." A welcoming feeling can result from small details, as one respondent mentioned: "There is a coat rack in the place where I need to hang my jacket."

Informality and ease

Some of the interviewees described the informal atmosphere of the place as the result of an equal and non-hierarchical work culture. Thus, as a researcher described, "We can talk and do things spontaneously without the formal preparation of meetings and permission-seeking." A staff member noted informal interactions as she described that "in situations where we, for instance, play games during or after the work ... we often touch upon work-related issues." She further mentioned that "nobody gives you a dirty look if you talk with people in the corridor about your weekend plans, and they may even join the conversation." A student explained the importance of the informal atmosphere to the campus environment by saying that "it creates the feeling that it is not compulsory for you to be here." Another student further stated that "I don't need to come to the campus anymore... unless I have courses with mandatory attendance." The student continued, "Informal and cosy environments have become the be-all and end-all of these kinds of places... otherwise, people do not come." A researcher added to this discussion by saying that "without informality, everything would function in more inflexible way... and people wouldn't come here anymore."

An entrepreneur described the informal space solution by saying that "if you think of it conversely... a formal space has a main door, reception, a long corridor with private rooms and closed doors." Thus, informal spaces are "open spaces without walls separating people," as a student noted. Some of the staff members explained that they prefer offices with hot desks instead of personal desks. An entrepreneur mentioned places such as Kafis that bring people together because "the only coffee machine of the building is located there," as a staff member explained. A researcher noted that Kafis provides opportunities to "easily exchange a word with people you don't already know." Additionally, the funny and playful elements of the

spaces were mentioned. These elements include a foosball table and other games, a meeting room with funny hats hanging on the wall and funny signposts.

Inspiration and facilitation

The atmosphere or ambience of a place was seen as the cumulative effect of the environment, including both the people and the design of the space. As one researcher commented, “When you are in the place, it is hard to say what it should be like to have a good atmosphere, but when I’m feeling good, then the atmosphere of the place is also most likely good.” The atmosphere of the ADF was described using such terms as “immediate”, “open”, “dynamic” and “inspiring”. A student commented that “often you know what the ambience is in a lecture hall... here, it is unpredictable, and that is fascinating.” A staff member stated that the atmosphere of the ADF cheers one up. The ADF’s atmosphere can also support learning, as one student stated: “If the atmosphere is formal and uptight, it may be harder to internalise some issues... when coming to a joyful atmosphere with a hands-on attitude, you might go along with the learning spiral.” This result is aligned with the findings of McLaughlin & Walker (2012), who point out the significance of informal settings and learning environments.

Because the atmosphere was seen to be the result of people’s ways of communicating, spatial solutions and services were also considered to affect atmosphere. Bright colours and cosy spaces were frequently mentioned as solutions. In addition, matters such as the tone in which instructions are written and whether the doors were kept open were considered by a staff member. Another staff representative mentioned the rooms with imaginative decorations, such as a meeting room with birch forest wallpaper, and continued by imagining further purposes for these rooms: “These rooms could be designed to indicate a certain purpose, such as brainstorming.” Additionally, different materials and textures relating to the walls, floors or furniture were mentioned. For instance, a researcher considered the importance of carpets by saying, “If each step would clomp on a stone floor, the atmosphere would be instantly different.”

Constant narrative of spaces

A staff member stated that “there has to be an argument for why spaces are designed the way they are.” Thus, the meaning of the constant narrative of the spaces was noted by a researcher: “The look and feel of space goes hand-in-hand with that we claim we do here,” or as a staff member put it, “They [spaces] have a convergent message.” The narrative of the spaces was seen to relate to how the space is communicated outwardly, as one researcher stated: “These spaces tell a story... what we do here and what the way of thinking is.” This story was told by an entrepreneur as follows: “To bring people together that wouldn’t otherwise meet.” Another entrepreneur also described the space’s story: “You can change thoughts, experiences, test and try ... and there are different spaces to support the distinct phases of product development.” A student said, “This place correlates with the Aalto pioneering spirit and shows what Aalto can be at its best.” The narrative of spaces can be used to guide the users’ actions, as a staff member claimed: “A place has to communicate its purpose for existence, what people do there and how you can participate... and the rules of use.” Another staff member justified the role of the narrative by saying that “we can validate our existence because otherwise, outsiders may see this place as an adults’ amusement park.” Another staff member said, “We [ADF staff] have to tell the story during the tours, so it’s good that all of us know it.” The co-narrative of place was also seen as a tool for space development because it steers the action in the same direction.

Some spatial solutions that support the constant narrative of the spaces, such as the consistent look of guideposts and signs, were mentioned during the interviews. One staff member said, “We use many sticker guides [that are fastened to the furniture]... and the font is Aalto style.” The use of similar furniture and colours for decoration was also mentioned. The space’s instructions were further noted by a staff member: “If we want the space to remain orderly... do we scare the users... or communicate in fun way.” Another staff member narrated a situation that occurred after the placement of instructions with a picture of how the chairs should be left after the bigger multi-use spaces were used: “The chairs started to be stacked more often.” A researcher noted all types of prototypes and course posters that can be found in the ADF spaces: “They tell what has happened here and what had been possible to do.”

The summary of the results can be seen in Table 2.

Table 2: Summary of results

<i>Experience</i>	<i>Function</i>	<i>Examples of supporting spatial solutions</i>
<i>Sense of welcome</i>	<ul style="list-style-type: none"> • <i>Attract people</i> • <i>Opens people up</i> 	<ul style="list-style-type: none"> • <i>Consistently friendly doorbell-answering policy</i> • <i>Action can be seen right in the lobby</i> • <i>Availability of non-reservable spaces</i>
<i>Possibilities for multi-use of the building and spaces</i>	<ul style="list-style-type: none"> • <i>Suggest new ways of doing things</i> • <i>Support users’ activities</i> • <i>Increase the use rate</i> 	<ul style="list-style-type: none"> • <i>Different spaces for different functions</i> • <i>Spaces that can be modified according to different use purposes</i> • <i>Easily movable furniture (e.g., light or with wheels)</i> • <i>Use policy that allows the application of the space for different purposes</i>
<i>Permission to be oneself</i>	<ul style="list-style-type: none"> • <i>Enhance productivity and learning</i> 	<ul style="list-style-type: none"> • <i>Spaces that enables informal interaction</i> • <i>No traditional office look; relaxing, home-like spaces</i> • <i>24/7 access</i>
<i>Informality and ease</i>	<ul style="list-style-type: none"> • <i>Attract people</i> 	<ul style="list-style-type: none"> • <i>Open environment</i> • <i>Hot desks instead of private rooms or personal desks</i> • <i>Places that bring people together</i> • <i>Funny and playful decorative elements</i>
<i>Inspiration and facilitation</i>	<ul style="list-style-type: none"> • <i>Inspire</i> • <i>Enhance learning</i> 	<ul style="list-style-type: none"> • <i>Bright colours and cosy space solutions</i> • <i>Tone of instructions about the use of the space</i> • <i>Use of different materials and textures in decoration</i>
<i>Constant narrative of spaces</i>	<ul style="list-style-type: none"> • <i>Communicate purpose of existence of use</i> 	<ul style="list-style-type: none"> • <i>Design reflects the aim of the place</i> • <i>Visually and verbally consistent space-use instructions</i> • <i>Use of similar furniture and colours</i> • <i>Displays of course outcomes, such as prototypes and posters</i>

6 CONCLUSION

This research focused on investigating the user’s experience of an academic coworking place by applying the experience-based 6T usability framework model. The model proved to function as a user experience research framework. The user experience of the ADF that was reported in this study arises from the activities of and interactions between its users, and its spatial solutions seem to support the users’ experience. The user groups that participated this study included students, researchers, staff members and entrepreneurs. Some of the user experiences were common to all participants, but indications of user group-specific experiences also arose. For instance, the ADF building seems to be especially suitable for students in product development courses. Other students might be uncertain about whether the place was for them and how to gain access to it. Like the students, the entrepreneurs’ activities also re-

lated to product development, such as ideating and prototyping; however, the entrepreneurs also required spaces for meetings with customers, showrooms and networking. The researchers' main needs related to having a peaceful office environment with private desks, whereas staff members seemed to value a close and supportive community spirit as a base of action.

It should be noted that the findings of this study apply only to a limited group of ADF users. Thus, broader investigations should be made to generalise the findings. Qualitative user experience research possesses certain challenges. Basing the research design on the user experience model has an effect on the results: Different outcomes might be gained by using another framework or by not using a framework at all. The content of the pre-defined claims of the survey should be further verified to ensure that the survey is appropriately comprehensive and multifaceted. Additionally, the analysis process can affect research results in research that is based on researcher interpretation.

This research provides facility and workplace practitioners' concrete ideas of how to develop and maintain coworking places and spaces. Different groups of coworking place users may have distinct user needs that should be considered during the design and actualisation of such spaces. Furthermore, researchers can benefit from the results because they provide an example of how the user experience of places can be investigated.

REFERENCES

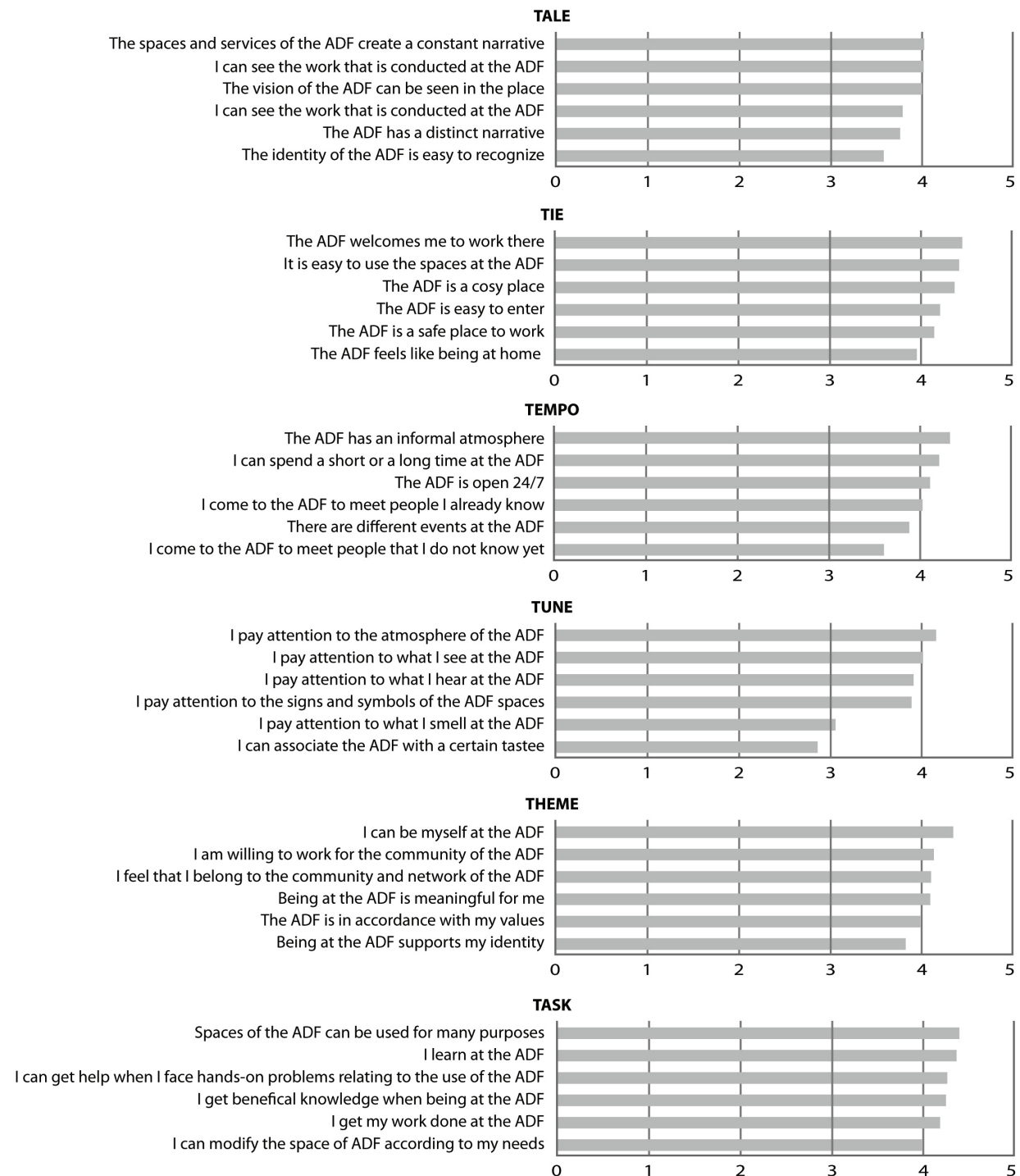
- ADF (2010), "Design Factory: Annual Report 2009-2010", available at: <http://www.aaltodesignfactory.fi/about/for-media/> (accessed 14 November 2013).
- ADF (2012), "Aalto Design Factory Stories: Annual Report 2011-2012", available at: <http://www.aaltodesignfactory.fi/about/for-media/> (accessed 14 November 2013).
- Ahmad, A. J. and Ingle, S. (2011), "Relationships Matter: Case Study of a University Campus Incubator", *International Journal of Entrepreneurial Behaviour & Research*, Vol. 17, No. 6, pp. 626-644.
- Alexander, K. (2010), "Usability of Learning Environments", in Alexander, K. (Ed.), *Usability of Workplaces – Phase 3*, International Council for Research and Innovation in Building and Construction, pp. 5-16, Rotterdam.
- Alexander, K. (2008), "Usability of Learning Environments", in Alexander, K. (Ed.), *Usability of Workplaces - Phase 2*, International Council for Research and Innovation in Building and Construction, Rotterdam, pp. 5-16.
- Bates, T. (2006), "Community and Collaboration: New Shared Workplaces for Evolving Work Practices", MA thesis, Massachusetts Institute of Technology.
- Bilandzic, M., and Forth, M. (2013), "Libraries As Coworking Spaces: Understanding User Motivations and Perceived Barriers to Social Learning", *Library Hi Tech*, Vol. 31, No. 2, pp. 254-273.
- Bostman, R., and Rogers, R. (2010), *What's Mine Is Yours: The Rise of Collaborative Consumption*, HarperCollins Publishers, New York.
- Braun, V. and Clarke, V. (2006), "Using Thematic Analysis In Psychology", *Qualitative Research in Psychology*, Vol. 3, No. 2, pp. 77-101.
- Creswell, J. W. and Plano Clark, V. L. (2011), *Designing and Conducting Mixed Methods Research* (2nd edition), Sage Publications, Los Angeles.
- DeGuzman, G. V. and Tang, A. I. (2011), *Working in the "UnOffice": A Guide to Coworking for Indie Workers, Small Businesses, and Nonprofits*, Night Owls Press, San Francisco.

- Diller, S., Shedroff, N. and Rhea, D. (2005), *Making Meaning: How Successful Businesses Deliver Meaningful Customer Experiences*, New Riders Press, Berkeley.
- Eraut, M. (2004), "Informal Learning in the Workplace", *Studies in Continuing Education*, Vol. 26, No. 2, pp. 247-273.
- Himanen, P., Au, A. and Margulies, P. (2011), "The New Incubators", *World Policy Journal*, Vol. 28, No. 3, pp. 22-34.
- Huwart, J-Y., Dichter, G. and Vanrie, P. (2012), "Coworking: Collaborative Space for Microentrepreneurs (Technical Note #1)", European Business and Innovation Centre Network EBN, Brussels.
- Inalhan, G. (2009), "Attachments: The Unrecognised Link Between Employees and Their Workplace (In Change Management Projects)", *Journal of Corporate Real Estate*, Vol. 11, No. 1, pp. 17-37.
- ISO (1998), ISO 9241-11, Ergonomic Requirements for Office Work With Visual Display Terminals (VDTs) - Part 11: Guidance on Usability, International Organization for Standardization.
- Jankowska, M. and Atlay, M. (2008), "Use of Creative Space in Enhancing Students' Engagement", *Innovations in Education and Teaching International*, Vol. 45, No. 3, 271-279.
- Joffe, H. and Yardley, L. (2004), "Content and Thematic Analysis", Marks, D. and Yardley, L. (Ed.), *Research Methods for Clinical and Health Psychology*, Sage Publications, London, pp. 56-69.
- Johnson, R.B. and Onwuegbuzie, A.J. (2004), "Mixed Methods Research: A Research Paradigm Whose Time Has Come", *Educational Researcher*, Vol. 33, No. 7, pp. 14-26.
- Kojo, I., Keltikangas, K. and Hänninen, J. (2013), "Developing Learning Environments for Engineering Education: Elements of User Experience and Supporting Spatial Solutions", paper presented at the 41th SEFI Conference, September 16-20, Leuven, Belgium.
- Kojo, I., Nenonen, S. and Santamäki, E-M. (2011), "Defining a workplace Experience Framework: Analyzing the Social Heartbeat of Aalto University Design Factory", paper presented at the first EUCEET Association Conference, November 24-25, Patras, Greece.
- Kvale, S. (1996), *InterViews: An Introduction to Qualitative Research Interviewing*, Sage Publications, California.
- Lindahl, G., Hansen, G. and Alexander, K. (2012), "The Usability of Facilities: Experiences and Effects", in Alexander, K. and Price, I. (Ed.), *Managing Organizational Ecologies: Space, Management and Organization*, Routledge, New York, pp. 105-116.
- Lumley, R. (2013), "A Coworking Project in the Campus Library: Supporting and Modeling Entrepreneurial Activity in the Academic Library", *New Review of Academic Librarianship*.
- Matthews, K.E., Andrews, V. and Adams, P. (2011), "Social Learning Spaces and Student Engagement", *Higher Education Research & Development*, Vol. 30, No. 2, pp. 105-120.
- McLaughlin, P. and Faulker, J. (2012), "Flexible Spaces ... What Students Expect from University Facilities", *Journal of Facilities Management*, Vol. 10, No. 2, pp. 140-149.
- Montgomery, J. (2007), "Creative Industry Business Incubators and Managed Workspaces: A Review of Best Practise", *Planning, Practice & Research*, Vol. 22, No. 4, pp. 601-617.
- Nenonen, S. and Kojo, I. (2013), "Experience of Places: Six Dimensional Model for Capturing the User Experience", paper presented at the EuroFM13, May 22-24, Prague, Czech Republic.
- Olma, S. (2012), *The Serendipity Machine: A Disruptive Business Model for Society 3.0*, Creative Commons.
- Parrino, L. (2013), "Coworking: Assessing the Role of Proximity in Knowledge Exchange", *Knowledge Management Research & Practice*,

- Preiser, W.F.E., Rabonowitz, E.T., and White, E.T. (1988), *Post-Occupancy Evaluation*, Van Nostrand Reinhold Company, New York.
- Spinuzzi, C. (2012), "Working Alone Together: Coworking as Emergent Collaborative Activity", *Journal of Business and Technical Communication*, Vo. 26, No. 4, pp. 399-441.
- Tähtinen, S., Kojo, I. and Nenonen, S. (forthcoming), "User Experience of Creative Class District: Studying Punavuori Neighborhood in Helsinki", CIB Facilities Management Conference, May 21-23, Copenhagen, Denmark.
- Thomas, J. (2012), "Creating Effective Learning Environments: Meetings the Challenges", in Alexander, K. and Price, I. (Ed.), *Managing Organizational Ecologies: Space, Management and Organization*, Routledge, New York, pp. 212-221.

Appendix 1: Predicate questions with the mean values of the ADF survey responses

Please evaluate the following statements. Focus on what you consider important, not how well the building supports the statements at the moment.



9.2

FACILITATING INTERDISCIPLINARY LEARNING COMMUNITIES: A CASE STUDY FROM FINLAND

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ABSTRACT

Purpose: The aim of this study is to analyze processes of five intrinsic interdisciplinary university space development projects on one university campus.

Background: The natures of university core functions have evolved drastically since the majority of university facilities have been built. Yet, only a small portion of campuses has been transformed to meet the new demands. At the same time, utilization rates and interdisciplinary synergies are low.

Approach: This study bases on literature streams of knowledge management, learning spaces, and university campus management. The preliminary data were collected by conducting seventeen semi-structured interviews with people involved in five space development projects in one campus. Supporting data include seminar presentations, informal discussions, visitor insights, and archival documents such as annual reports.

Results: Results suggest the projects be examined in five iterative phases. Common characteristics for all examined cases include: a bottom-up approach, retrofitting existing spaces for multiple purposes, agile prototyping methods, and constant development after opening.

Practical implications: The results propose the traditional role of university campus managers be expanded to include proactive facilitation and support of user-driven initiatives. Thus, they should: focus on the changing needs of end user communities on the campus; collaborate with internal and external partners; identify new activities that form effective learning and working processes; facilitate multi-usability of spaces; and increase synergies among space users.

Research limitations: This study is limited to intrinsic space development projects that relate to an on-going organizational change. Thus, the validity of the results in other contexts might be low. A quantitative approach might provide approval of the values the cases generate for the university.

Originality/value: By providing results on alternative development processes on university campuses, we hope this study offers valuable insights for the university administrators, facility managers and researchers.

Keywords: Interdisciplinary facilitation, University campus management, Learning communities, Knowledge creation, Organizational management

1 INTRODUCTION

Natures of working and learning are affected by evolutions of scale, time, and complexity in an increasingly interconnected, networked world (OECD 2001, OECD 2008, Den Heijer 2011, Bygdsdt 2013). Availability of information is shifting the expertise needs from narrow specialization towards valuing general adaptation (Neary et al. 2010). New ways of working and learning are less dependent on space, time and location impacting organizational actions and challenging traditional physical settings and their management (Worthington 2001; Joroff 2002).

More specifically, three learning space configuration trends deriving from the knowledge management and organizational paradigm shifts in higher education can be identified:

1. the physical paradigm shift from formal mono- to informal multi-use spaces (Long and Ehrmann 2005, Milne 2006, Dugdale 2009)
2. the social paradigm shift from teacher-centered pedagogy towards interactive student-centered education (Somerville and Brar 2010, Brown and Long 2006)
3. virtuality as an enabler deriving from technological development blurring boundaries between space types (Shabha 2004, Milne 2006, Dugdale 2009).

Traditional practices in the field of university campus management tend to concentrate on providing fixed facilities for specific purposes of mono-disciplinary units. However, given the low utilization rates, facing the uncertainty of university's societal role in the future, understanding the change in organizational structures and noticing the increase of multi-disciplinary research during the last years, a demand has emerged for spatial concepts housing multiple disciplines and also partnering organizations in shared premises. In the private sector, a demand for greater flexibility in organizational space arrangements had emerged earlier (Becker 2001, Gibson 2000; 2001, O'Roarty 2001, Worthington 2001). Deriving from the demand, a variety of new kinds of alternative space concepts evolved including serviced offices (Becker 2001), distributed workplaces (Harrison 2001), office hotels (Becker 2001), collaborative hubs and creative business incubators (Montgomery 2007).

However, in higher education facilities research and practice, alternative collaborative concepts have mainly been developed from libraries (i.e. Shuhuai et al. 2009, Bilandzic 2013) or campus incubators with a focus on high-tech industry firms (i.e. Ahmad and Ingle 2011). Moreover, the majority of the best practice research on higher education facilities has mainly focused on learning spaces in general (Dugdale 2009, McLaughlin and Faulkner 2012), laboratory spaces (Potkonjak et al. 2013), libraries (Sackett 2001, Rizzo 2002, Massis 2010, Cocciolo 2010), office spaces (Gorgievski et al. 2010), or campuses as entities (Den Heijer 2011). Not many studies have been conducted on the processes behind university campus development projects that aim at facilitating collaboration between interdisciplinary, cross-organizational individuals and units.

Therefore, this study takes a qualitative multiple case study approach to examine five such cases on one university campus in Finland. The aim is to analyse the processes of the projects. The research questions are: what kind of similarities and differences there are between the project processes, what kinds of values these projects offer for the university and how these types of projects can be supported. All the projects are situated on one campus of the same university and aim to function as platforms for interdisciplinary activities in a situation where three old universities have merged to one organisation.

The study at hand is structured under five main sections. The evolving learning environments section reflects the relation of knowledge management, learning spaces, and university campus management literature streams with the empirical demands and solutions in the field. The approach section outlines the empirical field and the qualitative research methodology employed. The results introduce the main findings of the cases by drawing upon the issues discussed in literature. The practical implications discuss potential use cases of the results for practitioners and researchers. Finally, the conclusions highlight the core message of the study.

2 EVOLVING LEARNING ENVIRONMENTS

The natures of learning and working are constantly changing because of evolutions in scale, time, and complexity (Bygst 2013). Radical future scenarios for schooling (OECD 2001), Higher Education (OECD 2008), University campuses (den Heijer 2011) and the nature of learning from institutional towards learning flows (Institute for the Future 2013) have been proposed deriving from technological advancements, globalization, increasing competition and changes in university funding. In case the most radical scenarios take place, profound changes for both the university and the campus managerial practices are needed (Rytkönen and Nenonen 2013).

The value hierarchy in universities has been assaulted over the past decades from a variety of fronts: from the changing map of knowledge, with its corrosion of disciplinary boundaries; from the emerging inter-professionalism of the academic enterprise – teaching as well as research (as other expertise); and finally from management. According to Hamel, the modern organizational problems cannot be solved by standardization, specialization and hierarchy (Barsh 2008) and even a shift towards spatial theory of organizations is suggested (Tissen and Deprez 2008).

Den Heijer (2011) employs an application of Corporate Real Estate Management (CREM) theory in defining university campus management as: “The range of activities undertaken to optimally attune the university’s accommodation to the university’s performance”. Here, the university’s accommodation is limited to land and buildings. Moreover, Den Heijer (2011) introduces an integrated model based on four crucial aspects and stakeholders to consider in each university campus decision: the physical perspective of the technical managers, the financial perspective of the controllers, the functional perspective of the users, and the strategic perspective of the policy makers. This approach supports risk identification and management but is static by nature and lacks reflections of campus processes and outcomes, the networked nature of university environments, causalities between different stakeholders, or new spatial development concepts (Rytkönen 2014).

In order to contribute to the dominating view of facilities management (FM) as an engineer-based resource-driven discipline, some scholars propose that qualitative approaches should be

highlighted more (Alexander 2012, Lindahl et al 2012, Coenen and Felten 2012). Because of its roots in natural sciences, the actual uses of spaces are not taken into as profound consideration in FM (Vischer 2012). The measures are important but the idea of managing walls, roofs, and floors is outdated and could thus be contributed to by a more user-centric, service-oriented approach needed in FM (Alexander 2012). In practice, FM is not only about managing facilities, but the essence of it is merely about managing the processes of human actors' engagement with these facilities (Cairns 2012). The essence is to understand the user processes.

The user processes are evolving simultaneously with the paradigm shifts of physical, social, and virtual dimensions of space. The transformation of the world to ever more complex structures seem to shift demands of narrow specialization in one discipline towards a need for more *multidisciplinary*, *interdisciplinary* and *trans-disciplinary* research and educational activities forming systemic entities from siloes (Gibbons et al. 1994, Ziman 2000). Nonaka (1991) highlights the role of tacit over explicit knowledge, the forms of human knowledge that were first introduced by Polanyi (1958). Nonaka and Konno (1998) introduced the concept of *ba* that constitutes the shared context for knowledge creation in physical, social and/or virtual dimensions. A *ba* is not limited to organizational boundaries but can also include the external parties in knowledge sharing and co-creation (Nonaka et al 2000, Nonaka and Toyama 2003).

Thus, the intangible knowledge creation processes of both research and learning seem to be collaborative, and they can benefit from and be supported by physical and virtual structures and concepts. In learning environments, these processes should be supported by both small and large scale solutions.

According to multiple scholars (Long and Ehrmann 2005, Milne 2006, Dugdale 2009), the need of multi-use learning environments is increasing as the existing learning space structures are inadequate to support the needs of students in the Internet era. The presently educated generations have grown up with the Internet, which has developed their natural way of consuming, distributing, sharing and creating information (Oblinger 2003, Prensky 2005, Windham 2006, Lippincott 2007). Learning landscape should support different ways of learning in and between multiple spaces supporting the whole learning cycle (Nenonen 2005). Informal interactive spaces are considered natural for people to learn in (Somerville and Brar 2010) and effective in enhancing learning compared to the formal un-interactive spaces such as traditional classrooms (Long and Ehrmann 2005) which is why informal learning models are taking over formal preacher models.

Although the technology and ways people act have evolved a lot during the last decades, the building design still follows the standard process it has followed for at least 20 years (Milne 2006). To answer the demands of educational development, also the design concepts should be developed towards more human-centric approaches than before (Brown and Long 2006). As academic units in university organizations establish the educational criteria for the actual users of spaces, a tighter connection between users and both administrative and service units are required to understand the real needs of the users (Somerville and Brar 2010). The priority should be on facilitating the actions taken inside the space, not on physical features inside the space (Alexander 2012, Rytönen and Nenonen 2013).

To summarize, the shifts from narrow disciplines to wider perspectives and border-crossing actions require profound changes in both university and campus management practices. The development of new collaborative learning and working environments is about processes, people, interaction and places supported by spatial and virtual structures.

3 APPROACH

A relevant empirical context to examine the challenges discussed is Aalto University in Finland. Aalto University merged in 2010 from original universities of business, technology and arts, and it aims to support interdisciplinary synergies in order to create innovations. The former three main campuses will be centralized to one main and one satellite campus by 2015, and the change process is on-going while executing this study. Multiple alternative space development projects have evolved in the future main campus between years 2008 and 2014.

The five intrinsic space development projects of this study are located in the same campus and range in size between 750 and 3200 sqm, one of the cases consisting of a network of nodes around the campus and other cases covering a whole building or part of a building.

The preliminary data were gathered by recording seventeen semi-structured interviews between one researcher and one interviewee at a time. The data were gathered by the first (2013) and the third author (2012) of the paper. The interviewed persons consisted of eleven project initiators or project staff members, two campus and facilities service staff members, one real estate owner representative and three voluntary students who were involved in the projects. The literature interviews were examined and analyzed by conducting within-case, between-case and cross-case analyses. The interviews were complemented with secondary data: seminar presentations, informal group meetings, visitor insights, archival publications, and other articles reporting the cases.

4 RESULTS

“Do we only provide premises and say ‘do what you want but these are the terms of condition?’” - University administration

According to the interviews, the Campus and facility services and the Real estate owner of the university in these projects have rather played roles of administrative supervisors than service providers or producers. They find the cases important, interesting and necessary but complicated and risky because the boundaries and responsibilities between actors are not clear. However, the more people these projects have attracted the better the administration has been capable of supporting these kinds of projects. Moreover, the issues of these cases from the university campus managers' aspect relate, in addition to monetary control, mostly to the traditional organizational management principles such as standardization, hierarchies, and specialization (Hamel in Barsh 2008) – whether all the spaces fulfill all the technical standards, who is responsible for possible faults, whether the processes follow the correct hierarchical orders and whether the initiators are qualified with a valid certificate for executing the development tasks and providing the services.

“There is a mindless amount of space with very low utilization or about totally empty in the university... we hope that (...) we could get rid of useless spaces and no money

would be allocated in vain but direct the money to the main purposes of the university – education and research.” - University administration

According to the interviews, the case processes can be divided into five overlapping phases: the initiative, the pre-development, the development, the evolution, and the value creation phase.

4.1 Initiative phase

The Initiative phase covers the time between the initial idea of an emerged demand in an individuals' mind to searching a space where the development could take place. Each project has a distinct group of initiators none of whom represents the official Campus and Facilities Services organization. Moreover, the initiators are former space users who have identified a demand, developed concepts and become co-producers of spatial services. This bottom-up approach has seemed to offer flexible solutions for thematic communities. It suggests an alternative paradigm supporting a top-down approach, typical for facilities management services, which tends to result in offering fixed solutions for a mass of people.

“Coming from outside, everything in the University is new to me, when establishing a new platform there is no direct reference point to me.” - Project staff member

The first project, *Design Factory*, was a spin-off of a research project conducted in the former University of Technology. The initial purpose of the research was to examine the possibilities of supporting product development education with spatial design solutions. During the execution of the research, the organizational merger of the three universities was proceeding and a need for examining interdisciplinary space facilitation to foster the interdisciplinary agenda of the new university emerged.

“...the process is to recycle the spaces of Aalto University that are not used currently and converting them into something more interesting, something more useful for the people of the University” - Project staff member

Inspired by the culture in the facilities of *Design Factory*, the second case, *Startup Sauna*, was initiated by a group of students who founded a student-led entrepreneurship society which had expanded rapidly and needed their own spaces. The third case, *AaltoHUBs*, was originally based on a student research and conceptualization project in an interdisciplinary study program and was initiated by a representative of a service unit inside the university. The fourth case, *ADDlab*, began evolving when a case representative noticed the merger of the new interdisciplinary university in Finland while teaching in the United States and identified an opportunity of introducing a 20-year evolved technology of digital manufacturing and 3D-printing leading to an idea of pioneering it in an interdisciplinary university context. Inspired by the other cases and international collaboration hub examples, the fifth case, *Urban Mill*, began as a spin-off from a research project, which concentrated on innovative urban area and knowledge hotspot development.

“...what was missing was the research and existing company layer...” - Project staff member

4.2 Pre-Development phase

The Pre-Development phase covers the time between finding a potential space and opening for the first time. According to the interviews, each space has been utilized for different pur-

poses by the former tenant and afterwards taken over by a space operator other than the campus service unit. All the design and execution processes have been relatively fast – the stage from knowing the assigned building and getting the keys to converting the spaces and opening has only lasted from one to three months in every case. The initial development budgets have been relatively low.

“when we came in, this hadn’t been occupied in five years - it had been used as a storage / dump” - Project staff member

The development project of Design Factory that was based on a research project was expanded from housing a floor of another building to cover a former wood research building from which a former tenant had moved away. It was decided that the building be modified by the researcher team according to the findings of the initial project over less than three months in summer 2008. The facilities for Startup Sauna used to be employed to storing hand sanitizer products for the campus restaurants. The suggestion for the initial layouts for Startup Sauna were made in a week, and a group of students from the different schools to be merged the next year, were authorized to manage the development process during three months in the summer of 2009. AaltoHUBs that initially started as a student project in 2010 was expanded to apply the results in practice searching for overlooked spaces in all the campuses, the modification processes of which would be lasting about three months depending on the case.

“The overall idea was to not make a very large investment but to make the space in a way that would be different from the surrounding areas”- Project staff member

ADDlab, opened in 2012, was attracted by an empty space utilized for furniture storage in a strategically wise location for the theme in the existing campus infrastructure. Urban Mill’s initiators were searching for a decent space in 2013 to examine spatial and operational solutions for innovative areas when a tenant moved away from neighborhood of Design Factory and Startup Sauna enabling collaboration with the other two pioneer cases.

“The biggest potential is in solving the problem that knowledge isn’t... like flowing here. People are just behind the locked doors and you don’t know what they are doing.” - Voluntary student

4.3 Development phase

The Development phase covers the development philosophy over time. The interviews indicate that the development philosophies of all the cases are more agile and reactive than in the traditional FM and construction processes including rapid prototyping and constant observation.

“What does it mean to have interdisciplinary actions? And we could show it – this is it. For this purpose we made the facility so that it can be tested.”- Project staff member

As Design Factory strove to support product development education, the researchers continued to test the applicability of agile prototyping, observation, and iteration methods from product development to spatial design and management. Startup Sauna is facilitated by students. They embrace the community in its development processes and collect constant feedback trying to fix identified faults. Otherwise, the physical environment is rather stable func-

tioning as a working and event space, and as a showroom for some of the inventions created in the facilitated programs.

“...we want to gather people interested in this theme together...” - Project staff member

ADDlab consulted a group of outsiders who gave suggestions for branding the space. The development was contributed to by the university student association that collaborate by facilitating a cafeteria and a space reservation system inside the spaces. The operators of Urban Mill employ the effectuation principles of Sarasvathy (2001) and Lean thinking (see, i.e. Jylhä 2013) in the development processes utilizing the existing resources and executing at an early stage rather than planning every detail in advance. It is run by two key initiators who aim at inspiring a community consisting of a variety of stakeholders to build the space and facilitate events.

“each space is a prototype so every time we try out something else... - we do things, we learn from them, we apply the knowledge in the next prototype. And it is done by cross-unit group of like-minded people.” - Project staff member

The development practices of AaltoHUBs differ significantly from the other cases by a community-involving prototype philosophy. Each development initiative is taken by the same initiator who runs the process but each project is co-produced and co-designed separately with representatives of the respected community occupying the building.

“The prototype phase revealed that certain actors were interested in this theme and thus, they invested a small amount of money to support the idea.” - Project staff member

4.4 Evolution phase

The Evolution phase covers the evolution of the concept in a wider sense. The interviews revealed that the majority of the case representatives consider their physical space a never-ready prototype. Due to strategic or project-based funding the cases are based on, the spatial entities function in a project-based manner which keeps them evolving. None of the cases have departmental or institutional status but are rather collaborative platforms, which also fosters their on-going evolution. Although each space operator knows and helps each other, each case is managed and run autonomously by a different operator. Each project is also active in on-line communications (see more information on the cases in the references).

“... 200,000 € covers the invisible things and 200,000 € covers the abilities why it still exists... there should be some money for some modifications after opening...” - Project staff member

Design Factory has been exported to four continents, the processes of which have been monitored in order to learn more about the cultural differences and values the concept offers. The spatial solutions of Startup Sauna and ADDlab are rather stable but function as showrooms for what is being created in the spaces. AaltoHUBs bases on observations and learnings from the earlier developments. Urban Mill evolves constantly through community actions as actors furnish the raw space and install their project prototypes and posters on the walls.

“...all we can achieve by space planning is to minimize the limiting abilities of space...” - Project staff member

The case projects differ from traditional space projects as they are constantly developed based on issues observed and potential demands of the users. This is why the initial timely and monetary investment for planning and developing these spaces is rather small. But as the iterative development methodology requires testing, the on-going evolution phase requires its own budget. Compared to the traditional construction processes where fixed solutions are planned in advance and executed at once with one budget without observing-based development afterwards, these projects tend to require a more dynamic budget because of the contextual prototyping. All the projects have gained strategic funding from the university but also from other sources in forms of industry collaboration projects and donations. The initial space development budgets of the cases vary from 1000 euros to 400,000 euros but are not precise. All cases work as living labs, some including courses for testing and developing the facilities, and thus, the annual running and development budgets can reach up to a million euros.

“The spaces operate on three levels: physical, virtual and social...” - Project staff member

The on-going evolution also requires both physical and virtual social facilitation. In the interviews, the roles of janitors, peers and mentors running events, communicating and helping out when needed were emphasized to a great extent. Thus, the evolution phase requires also an extensive HR and event facilitation investment which enables the daily operations of these spaces. Because of the community-based thematic ideologies behind, these services are difficult to outsource.

“...it was not just about the content and research being done here but also testing certain models for Aalto general development.” - Project staff member

4.5 Value creation phase

The value creation phase starts from the initial opening of the space. The cases are similar in aiming at both internal and external interdisciplinary collaboration by uniting education, research, and industry activities focused on a certain theme in the same space. The general added value aim of all the cases seems to be synergy facilitation between disciplines and organizations in order to make a local or a global impact in the end. For a young university consisting of traditional units in the middle of a massive organizational change, these values are valid and in line with the strategic and campus visions of the university.

However, the main values the cases create for the university vary based on their functional mechanisms. One of the projects focus mainly on student-industry collaboration through facilitating interdisciplinary courses, one on promoting entrepreneurship matching startups with venture capitals through arranging a variety of events and programs, two on research-industry collaboration around their themes, and one on creating a network of learning spaces facilitating internal, and increasingly external, communications. One of the projects aims at fundamentally changing the business logic of university facilities.

“The value is wholly created by the community.” - Project staff member

Change in the bureaucratic principles of the academic culture is another valuable aspect the interviews revealed. As radical interdisciplinary actions have not been implemented to a wide extent, these cases also function as valuable test beds for testing models for general university level developments. And they attract interest towards the institution as they showcase the

work done in the University. The main characteristics of each case are listed in Table 1 and the processes are illustrated in Figure 1.

Figure 1: A common conceptual illustration of the case project phases



Table 1: The main factors leading to each phase of the project cases

Factors leading to:	Case 1: Design Factory	Case 2: Startup Sauna	Case 3: AaltoHUBs	Case 4: ADDlab	Case 5: Urban Mill
Initiative phase	Organizational change on top. Research project on bottom.	Growing student-led entrepreneurship society.	Organizational change on top. Research project on bottom.	Organizational change on top. Evolving technology.	Organizational change on top. Research project on bottom.
Pre-development phase	Tenant move from building	Overlooked space used for storing hand sanitizer.	Overlooked spatial resources around the campus.	Overlooked space used for storing furniture.	Tenant move from building.
Development phase	Product-development, prototyping.	Student-run development and facilitation	Collaborative community inclusion.	Consultancy. Firm collaboration.	Effectuation (Sarasvathy 2001) and Lean (i.e. Jylhä 2013) principles.
Evolution phase	Project-like nature, international collaboration.	Community demands.	Accumulative prototypes.	Showrooming, discourse, café facilitation.	Prototype, community to set up the space.
Value creation	Student-industry collaboration through courses. Test bed for research. Global interest.	Promoting and enforcing entrepreneurship. Connecting external actors to university. Global interest.	Increasing interdisciplinary communications. Increasing library utilization rates. Local interest.	Research-industry collaboration. Possibilities for innovations in 3D printing. Global interest.	Research-industry collaboration. Re-thinking the revenue logic of University facilitation. Global interest.

"... 'free money' for the research and startups, that is the big thing we are aiming at..." - Project staff member

"...a space enables a myriad things but does not create any value as such..." - Project staff member

In all, the case projects seem to be organically driven by individuals who have a vision and work hard to make it happen. Therefore, interesting space projects evolve. There seems to be a certain level of continuum between the cases and the interviewees referred to each other but each project functions as an autonomous entity. These projects seem less about facility management as such but more value is generated through community facilitation. The cases propose a holistic approach to facilitating organizational communities inside the facilities, in addition to facilities per se.

"We try to connect everything, create a dialogue and a discourse and somehow create content that would represent Aalto University towards the exterior"-Project staff member

5 PRACTICAL IMPLICATIONS AND LIMITATIONS

The results propose that organic interdisciplinary bottom-up development is difficult to manage but possible to facilitate. Based on the findings, we emphasize the hindrances and enablers listed in Table 2 as recommendations for campus and university managers.

Table 2: Enablers and hindrances for the university campus managers and university administration

Phase	Hindrances (-)	Enablers (+)
Initiative	-Leaning to traditional ways of operating.	+ Risk taking capabilities and hands-on attitude.
Pre-development	- Restrictions based on standards and specialization principles.	+ Focus on user needs, user involvement and overlooked spaces.
Development	- Prohibiting space use for informal events.	+ Efficient communications and event facilitation.
Evolution	- Command, control, hierarchies, bureaucracy.	+ Facilitation, empowerment, support, negotiations.
Value creation	- Traditional measures and standards.	+ Evaluation of efficiency and effectiveness. Costs vs values vs impacts.

This study is however limited to a few cases in a specific context and its validity in another context is open for critique. In the cases discussed, coincidence has played an inevitable role and thus the processes would be hard to replicate because they have happened rather organically. The interviews with the project initiators, students and services and administration staff combined with secondary data ensure reliability through triangulation of the data although the sample of the interviewed people is quite small. More people were interviewed on the initiator side than on the administrative side. As the cases seem to derive from an organizational change in general, their relation to organizational management and change theories should be studied. Moreover, the processes should be compared with those of the traditional ones in the same campus.

6 CONCLUSION

This study aimed to contribute to university campus management literature and practice through examining five alternative university space development projects that seem to follow the basics of knowledge management and learning space literature. The university campus management literature seems to be following behind the knowledge management and learning space literatures. The results propose a community-driven expansion to existing university campus management theories. The development philosophies suggest alternative bottom-up approaches in addition to the traditional top-down FM and development practices. Moreover, new ways of learning and working seemingly require more agile, systemic, and integrated processes from physical, social, and virtual facilitation. We hope these examples encourage university administration, facility management practitioners, university community members and researchers alike to ideate, test, implement and impact their own environments.

REFERENCES

- Ahmad, A. and Ingle, S (2011) "Relationships matter: case study of a university campus incubator", *International Journal of Entrepreneurial Behaviour & Research*, Vol. 17 No. 6, 2011, pp. 626-644, DOI 10.1108/13552551111174 701
- Alexander, K., and Price, I. (2012) *Managing Organizational Ecologies – Space, Management and Organization*. New York: RIOT.
- Alexander, K. (2012) "Chapter 13: Co-Creation of Value in FM." In *Managing Organizational Ecologies – Space, Management and Organization*, edited by K. Alexander and I. Price, 155–166. New York: RIOT.
- Barsh, J. (2008) "Innovative Management", A Conversation with Gary Hamel and Lowell Bryan, *McKinsey Quarterly* No.1, pp. 1 -10.
- Becker, F. (2001) "Organisational agility and the knowledge infrastructure", *Journal of Corporate Real Estate* Vol. 3 No. 1, 2001, pp. 28–37.
- Bilandzic, M. (2013) *The Embodied Hybrid Space – Designing Social and Digital Interventions to Facilitate Connected Learning in Coworking Spaces*. A PhD dissertation. Urban Informatics Research Lab, Creative Industries Faculty, School of Design, Queensland University of Technology.
- Brown, J. (2002) "Growing up digital – how the web changes work, education, and the ways people learn", *Journal of the United States Distance Learning Association*, Vol. 16 No. 2, available at: www.usdla.org/html/journal/FEB02_Issue/article01.html
- Brown, M. and Long, P. (2006) "Trends in learning space design", in Oblinger, D.G. (Ed.), *Learning Spaces*, EDUCAUSE, Boulder, CO, available at: <http://net.educause.edu/ir/library/pdf/pub7102i.pdf>
- Bygst (2013) "Campusudvikling Metode og proces" (Campus Development Method and Process), Bygningstilsynet and Styrelsen for Universiteter og Internationalisering. Retrieved 30.9.2013 in: <http://www.bygst.dk/om-os/publikationer/campusudvikling-metode-og-proces/>
- Cairns, G. (2012) "Chapter 8: Philosophical Contradictions in FM." In *Managing Organizational Ecologies – Space, Management and Organization*, edited by K. Alexander and I. Price, 94–104. New York: RIOT.
- Cocciolo, A. (2010) "Alleviating physical space constraints using virtual space? A study from an urban academic library", *Library Hi Tech* Vol. 28 No. 4, 2010 pp. 523-535, DOI 10.1108/07378831011096204.

- Coenen, C., and Von Felten, D. (2012) "Chapter 10: Service-Centric Logic of FM." In *Managing Organizational Ecologies – Space, Management and Organization*, edited by K. Alexander and I. Price, 117–127. New York: RIOT.
- Den Heijer, A. (2011) *Managing the University Campus, Information to Support Real Estate Decisions. A PhD dissertation. Delft, Netherlands: Eburon Academic Publishers.*
- Dixon, N. (1997) "The Hallways of Learning", *Organizational Dynamics*, Spring 1997, Available at: http://www2.warwick.ac.uk/fac/soc/wbs/exec/programmes/nhs_sath_reading/accommodation/dixon_hallways_of_learning.pdf.
- Dugdale, S. (2009) "Space Strategies for the New Learning Landscapes", *Educause review*, March/April 2009, pp. 51-62.
- Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., and Trow, M. (1994) *The new production of knowledge: the dynamics of science and research in contemporary societies*. London: Sage.
- Gibson, V (2000) "Property portfolio dynamics: the flexible management of inflexible assets", *Facilities* Vol. 18 No. 3/4 . 2000. pp. 150-154.
- Gibson, V. (2001) "In search of flexibility in corporate real estate portfolios", *Journal of Corporate Real Estate* Vol. 3 No. 1, 2001, pp. 38–45.
- Gorgievski, M., Van der Voordt, T., Van Herpen, S., Van Akkeren, S. (2010) "After the fire - New ways of working in an academic setting", *Facilities*, Vol. 28 No. 3/4, pp. 206-224. DOI 10.1108/02632771011023159.
- Harrison, A (2001) "Accommodating the new economy: The SANE space environment model", *Journal of Corporate Real Estate*, Vol. 4 No. 3, 2002, pp. 248–265.
- Institute for the Future (2013) "From educational institutions to learning flows", Retrieved 18.2.2013 in <http://www.iftf.org/our-work/global-landscape/learning/from-educational-institutions-to-learning-flows/>
- Joroff, M. (2002) "Workplace mind shifts", *Journal of Corporate Real Estate*, Vol. 4 No. 3 pp. 266 - 274. <http://dx.doi.org/10.1108/14630010210811886>
- Lindahl, G., Hansen, G., and Alexander, K. (2012): "Chapter 9 The Usability of Facilities – Experiences and Effects." In *Managing Organizational Ecologies – Space, Management and Organization*, edited by K. Alexander and I. Price, 105–115. New York: RIOT.
- Lippincott, J.K. (2007), "Student content creators: convergence of literacies", *EDUCAUSE Review*, Vol. 42 No. 6, pp. 16-17, available at: www.educause.edu/apps/er/erm07/erm07610.asp
- Long, P. D., & Ehrmann, S. C. (2005). *Future of learning spaces – breaking out of the box*, *Educause review* July 2005.
- Massis, B. (2010) "Project management in the library", *New Library World*, Vol. 111 No. 11/12, pp. 526 – 529. DOI 10.1108/03074801011094895.
- McLaughlin, P., Faulkner, J.D. (2012) Flexible spaces...what students expect from university facilities, *Journal of Facilities Management [E]*, Vol 10 No. 2, Emerald Group Publishing Ltd., UK, pp. 140-149.
- Milne, A. J. (2006). "Designing Blended Learning Space to the Student Experience", p. 11.2. In D. G. Oblinger, *Learning Spaces, chapter 11*, ISBN 0-9672853-7-2 (p. 15). Educause.
- Montgomery, J. (2007) "Creative Industry Business Incubators and Managed Workspaces: A Review of Best Practice", *Planning, Practice & Research*, Vol. 22, No. 4, pp. 601 – 617, November 2007, Routledge.
- Neary, M., Harrison, A., Crellin, G., Parekh, N., Saunders, G., Duggan, F., Williams, S. and Austin, S. (2010) "Learning Landscapes in Higher Education. Clearing pathways, making spaces, involving academics in the leadership, governance and management of academic

- spaces in higher education.” Centre for Educational Research and Development. University of Lincoln. United Kingdom.
- Nenonen, S. (2005). *The Nature of the Workplace for Knowledge Creation*. PhD dissertation. Helsinki University of Technology.
- Nonaka, I. (1991) “The knowledge-creating company”, *Harvard Business Review*, Vol. 69 No. 3, pp. 27-38.
- Nonaka, I., and Konno, I. (1998) “The concept of ‘Ba’: building a foundation for knowledge creation”, *California Management Review*, Vol. 40 No. 3, pp. 40-54.
- Nonaka, I., and Toyama, R. (2003) “The Knowledge-creation theory revisited: knowledge creation as a synthesizing process.” *Knowledge Management Research & Practice*, 2003, Vol. 1, pp. 2–10.
- Nonaka, I., and Toyama, R., and Konno, N. (2000) “*SECI, Ba and Leadership: a Unified Model of Dynamic Knowledge Creation*”, *Long Range Planning*, 2000, Vol. 33, pp. 5-34.
- Oblinger, D.G. (2003), “Boomers, Gen-Xers, & Millennials: understanding the new students”, *EDUCAUSE Review*, Vol. 38 No. 4, pp. 37-47, available at: www.educause.edu/ir/library/pdf/erm0342.pdf
- Organisation for Economic Co-operation and Development (OECD) (2001) “Scenarios for the future of schooling.” Chapter 3 in *Schooling for tomorrow project*, <http://www.oecd.org/site/schoolingfortomorrowknowledgebase/futuresthinking/scenarios/38967594.pdf>. Retrieved 30.9.2013.
- OECD (2008), “Future Scenarios for Higher Education”, Presentation in *OECD/CERI conference Higher Education to 2030: What Futures for Quality Access in the Era of Globalisation?* Dec 9 2008. Presented by Van Damme, D.
- O’Roarty, B. (2001) “Flexible space solutions: An opportunity for occupiers and investors”, *Journal of Corporate Real Estate* Vol. 3 No. 1, 2001, pp. 69–80.
- Polanyi, M (1958) *Personal Knowledge – Towards a Post-Critical philosophy*. University of Chicago Press. Chicago, IL.
- Potkonjak, V., Kosta, J. Holland, O, Uhomoibhi, J. (2013) “Distance learning and skill acquisition in engineering sciences. Present state and prospects”, *Multicultural Education & Technology Journal*, Vol. 7 No. 1, 2013, pp. 64-88, DOI 10.1108/17504971311312627
- Prensky, M. (2005), “Engage me or enrage me: what today’s learners demand”, *EDUCAUSE Review*, Vol. 40 No. 5, pp. 60-5, available at: www.educause.edu/ir/library/pdf/ERM0553.pdf
- Rizzo, J. (2002), “Finding your place in the information age library”, *New Library World*, Vol. 103, No: 11 pp. 457 – 466. DOI 10.1108/03074800210452987.
- Rytkönen, E. and Nenonen, S. (2013) “The Business Model Canvas in University Campus Management”, *Intelligent Buildings International*, DOI:10.1080/17508975.2013.807768. Published online: 20th Jun 2013.
- Rytkönen, E. (2014) “Community-focused perspectives to interdisciplinary university campus management – a business model case study”, to be published in *PRRES 2014 conference proceedings*, 19th-22nd Jan 2014.
- Sackett, J. (2001) “Planning the new central academic library”, *New Library World*, Vol. 102 No. 1165. 2001. pp. 207-210.
- Sarasvathy, S (2001) “What makes entrepreneurs entrepreneurial?” Available at: <http://www.effectuation.org/paper/what-makes-entrepreneurs-entrepreneurial>. Retrieved Nov 7th 2013.
- Shabha, G. (2004). "An assessment of the effectiveness of e-learning on university space planning and design", *Facilities*, Vol. 22 No. 3 pp. 79 – 86, available at: <http://dx.doi.org/10.1108/02632770410527815>, retrieved Oct 15th 2012.

- Shuhuai, R., Xingjun, S., Haiqing, L., and Jialin, C. (2009): "From information commons to knowledge commons - Building a collaborative knowledge sharing environment for innovative communities." *The Electronic Library*, Vol. 27 No. 2, 2009, pp. 247-257, DOI 10.1108/02640470910947593.
- Somerville, M. M., & Brar, N. (2010). From information to learning commons: Campus planning highlights. *New Library World*, Vol 111, No. 5/6, 179-188.
- Tissen, R., and Lekanne Deprez, F. (2008) "Towards a spatial theory of organizations - creating new organizational forms to improve business performance". Nrg working paper series, Nyenrode Research Group February 2008 no. 08-04.
- Vischer, J. (2012) "Chapter 3: FM for Human Capital Value." In *Managing Organizational Ecologies – Space, Management and Organization*, edited by K. Alexander and I. Price, 155–166. New York: RIOT.
- Windham, C. (2006), "Getting past Google: perspectives on information literacy from the millennial mind", *EDUCAUSE Learning Initiative*, available at: www.educause.edu/ir/library/pdf/ELI3007.pdf, retrieved Nov 7th 2013.
- Worthington, J. (2001) "Accommodating change — Emerging real estate strategies", *Journal of Corporate Real Estate*, Vol. 3 No. 1, 2001, pp. 81–95.
- Ziman, J. (2000). *Real Science. What it is, and what it means*. Cambridge: Cambridge University Press.

Additional information on the cases:

Aalto University www.aalto.fi
Design Factory <http://www.aaltodesignfactory.fi/>
Startup Sauna <http://startupsauna.com/>
Aalto learning hubs <http://aaltolearninghub.blogspot.fi/>
ADDlab <http://addlab.aalto.fi/>
Urban Mill <http://urbanmill.org/english/>

9.3

VALUE ADDING SPACE MANAGEMENT IN HIGHER EDUCATION

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ABSTRACT

Purpose: Develop a methodology for space optimisation in educational facilities, that can add value to organisations with particular focus on gymnasiums in Denmark.

Background: Gymnasiums are pre-university higher educational institutions, which in 2007 went from being state-owned to being self-governing. Many older gymnasiums face the challenge that the institutions' buildings and spaces are unsuitable to support modern teaching methods. A space optimisation process can help overcome some of these challenges as long as it makes use of a holistic analysis, is related to the strategic objectives of the organisation and reflects the organisational culture as well as the teaching methods.

Approach: The research is based on case studies of two gymnasiums utilising an array of different methods based on a combination of the evaluation methodologies Post Occupancy Evaluations (POE) and the Norwegian USEtool. The study examined which aspects should be included in a space optimisation process in order to add value and included extensive user involvement.

Results: A number of space optimisation initiatives that could lead to improvements in space utilisation as well as in the learning environment were identified. The study also provides a critical assessment of POE and USEtool, and proposes a new space optimisation process.

Practical implications: The research provides examples of how value adding space optimisation processes can be undertaken using a combination of different methods, including extensive user involvement, and recommends a new space optimisation procedure.

Research limitations: The research is based on two case studies of gymnasiums in Denmark, which limits the possibility to generalise, and the new recommended procedure has not been tested.

Originality/value: The study provides a critical evaluation of the combined use of POE and USEtool and represents an original contribution to the development of knowledge and methodology of value adding space management.

Keywords: Space Management, Higher education, Learning environment, Value adding, Case study

1 INTRODUCTION

The purpose of this research is to develop a methodology for space optimisation in educational facilities, which adds value to the organisations with particular focus on gymnasiums in Denmark.

Gymnasiums are pre-university higher educational institutions (HEI), and they currently face a number of challenges, which makes it relevant to optimise their use of resources, including the utilisation of space (Tinsfeldt, 2013):

- In 2007 all Danish gymnasiums changed from being state-owned to being self-governing and today they to a high degree function as independent companies.
- As part of the Danish state budget for 2012 the government in November 2011 decided to introduce a maximum number of 28 instead of earlier 32 students in each class in gymnasium educations.
- The public payment per student in gymnasium educations will be reduced during the period from 2012 to 2016, which will cause severe organizational and economic challenges for several institutions.
- The buildings belonging to many older gymnasiums are not suitable to support modern educational environments and teaching methods, which are prescribed in the recent reform of gymnasium educations.

A space optimisation process can help overcome some of these challenges as long as it makes use of a holistic approach and acknowledges, that space optimisation is not only about placing more people on less space but that it has an influence on the overall learning environment. A space optimisation process should according to literature be related to the strategic objectives of the organisation and reflect the organisational culture as well as the teaching methods.

The research is empirically based on case studies of two gymnasiums. The case studies included an array of different methods, such as document studies, interviews, walk-throughs, observations and questionnaire surveys. The methods were based on a combination of the evaluation methodologies Post Occupancy Evaluations (POE) and the Norwegian USEtool. The study examines which aspects should be included in a space optimisation process in order to add value. The space analyses were based on an extensive user involvement to provide insights in the opinions of the primary stakeholders.

Based on the evaluations the case studies identified a number of space optimisation initiatives for each gymnasium that could lead to improvements in space utilisation as well as in the learning environment. The research also included a critical assessment of POE and USEtool based on the completed space optimisation analyses and the development of a new space optimisation procedure which can be used to ensure added value at gymnasiums in general.

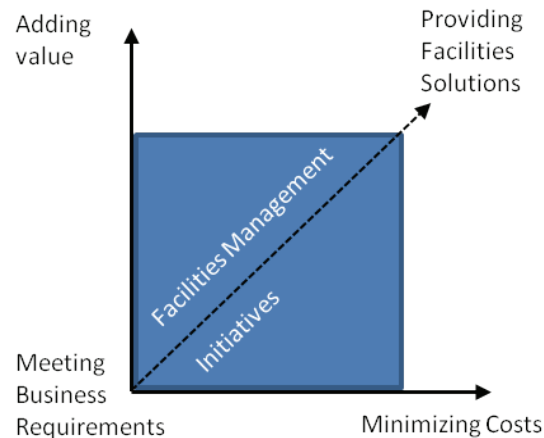
This paper briefly summarizes the empirical findings. However, the main focus is on the assessment of the evaluation methodologies and presenting the proposed space optimisation procedure.

2 STATE OF THE ART

Space Management (SM) is an essential aspect of Facilities Management (FM). The purpose of FM is to support and improve the effectiveness of the primary processes in an organisation (CEN, 2006). SM is about the management of space in facilities, and this paper particularly focuses on the management of space in educational buildings.

The development of FM has particularly in practice for a long time been dominated by a focus on cost reduction. Optimisation of space utilisation can be a very important way to save cost, because use of less square metres can reduce the cost for providing, operating and maintaining the space (Ibrahim et al., 2011). However, it is just as - or perhaps even more – important, that FM adds value to the organisation (Jensen et al., 2012), and improving the way the space supports the needs of the organisation is an essential way for FM to add value. This general dilemma for FM is illustrated in Figure 1. It is a crucial management task in FM to balance the demand and supply of space and at the same time balance the considerations for minimizing cost and adding value.

Figure 1: FM initiatives as a vector for change (Duffy et al., 1993, in McGregor and Then, 1999)



In accordance with this dilemma we can distinguish between two approaches to space optimisation. A quantitative approach which addresses space utilisation in terms of the amount of square metres with a main focus on reducing cost, while a qualitative approach focuses on changing the way that space is used to improve the effectiveness of the primary processes. In this research we want to combine these two approaches to develop a methodology that is aimed at achieving an optimised space utilisation and organisational impact at the same time. This is what we call Value Adding Space Management. It is important that the strategies for FM and SM are synchronised and aligned with the vision, mission and strategy of the core business organisation to achieve successful results (Mosbech, 2004).

A large number of methods have been developed for both quantitative and qualitative space analyses and evaluations. Quantitative measurements of space utilisation can provide important data, because the users' perceptions of space utilisation often are very different from the actual space utilisation (Ibrahim et al., 2012). A quantitative analysis will provide objective data about the company's space utilisation which hardly can be contested (Mosbech, 2004). However, there will often be special circumstances in the specific type of business or organisation that needs to be taken into consideration in quantitative analyses, for instance

hours of operation. Therefore, it is difficult to identify a generic process for collecting quantitative data.

There are some international studies of the quantitative space utilisation of higher educational institutions. Biddison and Hier (1998, in Downie, 2005) conducted such a study of American institutions showing a space utilisation in some institutions as low as 20% and rarely above 50%. A study by Downie (2005) in English institutions conducted in 2002 showed a space utilisation of approx. 50%. Che Ani et al. (2012) have developed an index for space utilisation as shown in Table 1. This has been used as a guideline in our study.

Table 1: Index for space utilization in higher education institutions (Che Ani et al., 2012)

Index	Range	Indicator	Usage intervals percentage	Description
1	0-1	Minimal Usage	0-50 %	The usage frequency at the low Level
2	1-2	Optimal Usage	51-75 %	The usage frequency at the best Level
3	2-3	Maximal Usage	76-100 %	The usage frequency at the high level
4	3-4	Critical Usage	>101%	The usage frequency at the crucial stage because it has exceeded the typical time

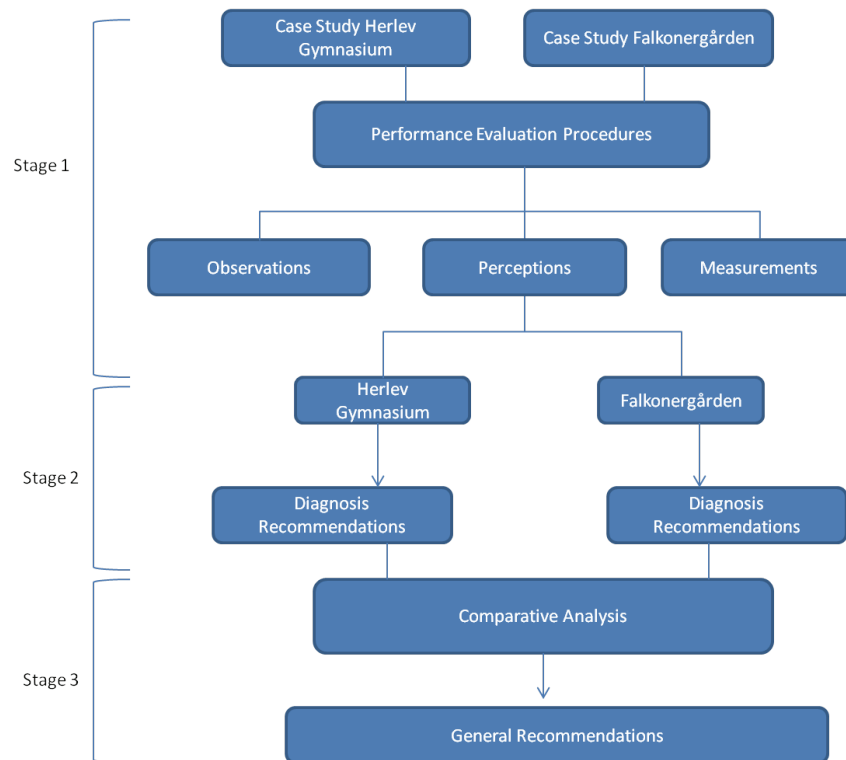
There have also been some international studies showing the qualitative importance and impact of educational facilities. The effectiveness and performance of students and teachers depends according to Earthman (2002, in Hasbullah et al., 2011) and Ismail (2002, in Che Ani et al., 2012) on the quality of their school environment. Furthermore, schools with modern and functional equipment give the students better opportunities to perform (Earthman, 2004). Even though technology has become a part of the modern school, there are still many school buildings that do not support the use of the technology, and which are far from supporting the teaching methods, which are commonly used in the 21st century (Kuuskorpi and Gonz  les, 2011). To achieve a satisfactory quality of education it is extremely important, that the buildings and the spaces in schools fulfil the requirements of society and FM has a crucial role in ensuring this (Mei-yeung and Fung, 2005).

3 APPROACH

The evaluation of the two case studies - Herlev Gymnasium and Falkonerg  rden - has in general followed the procedure for building evaluation with three stages which is recommended by Ornstein et al., 2005. The first stage is the data collection, the second is the analysis of each case with diagnosis and recommendations, and the third stage is a comparative analysis resulting in general recommendations. The procedure as adapted to our study is shown in Figure 2.

There are a huge number of different methods and techniques for evaluation of buildings and spaces in use with various combinations of qualitative assessments and quantitative measurements. Fronzcek-Munter (2013) has identified more than 150 different techniques. In this study we have used a combination of the more general methodology called Post-Occupancy Evaluation (POE) and the recently developed Norwegian tool for usability evaluation of buildings called USEtool.

Figure 2: The evaluation process (adapted from Ornstein et al., 2005)



POE was developed in the 1960's in USA and is today the most well-known method to evaluate buildings. The name refers to the evaluation being conducted after a building has been occupied. According to Preiser et al. (1988, Blakstad et al., 2010) POE is: “[...] *the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time*”. There are many versions of POE. In this study we have mostly used the version published by the Higher Education Funding Council for England (Blyth et al., 2006).

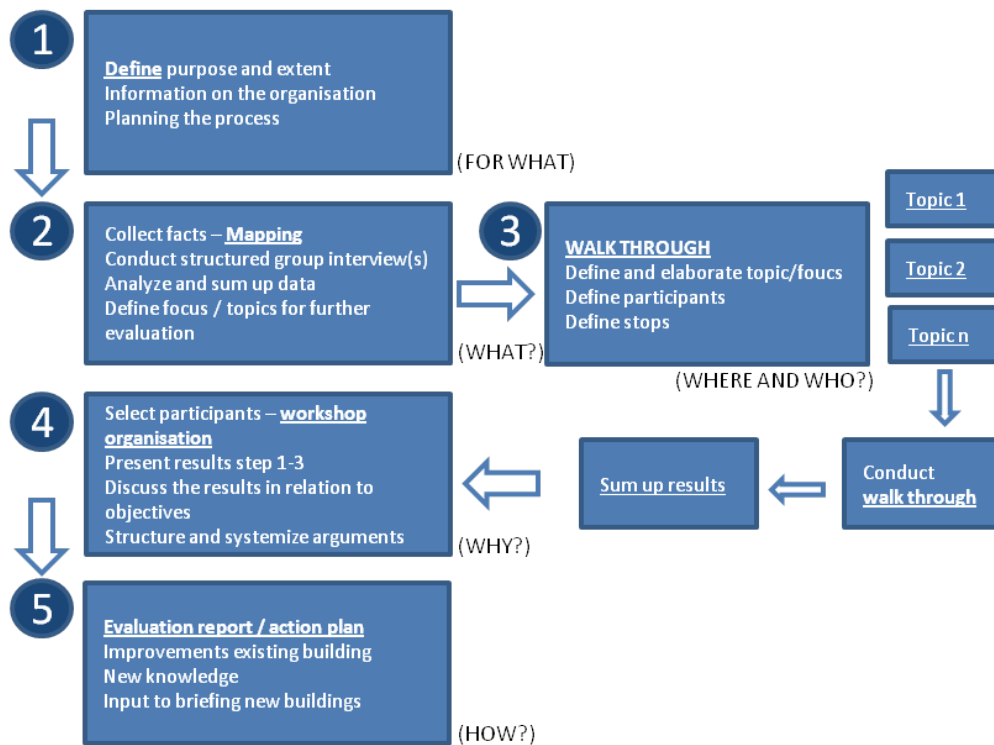
POE is in general divided in 3 areas: Process, Functional Performance and Technical Performance. In relation to space optimisation Functional Performance is most relevant and therefore this is the area of POE that has been of interest for our study. The different aspects that can be involved in a functional evaluation are shown in Table 2. Our study, however, has not included the cost aspects.

Table 2: Functional evaluation in POE (Blyth et al., 2006)

Strategic Value	Achievement of original business objectives.
Aesthetics and Image	Harmonious, natural, iconic, powerful, bland.
Space	Size, relationships, adaptability.
Comfort	Environmental aspects: lightning, temperature, ventilation, noise, user control.
Amenity	Services and equipment: completeness, capacity, positioning.
Serviceability	Cleaning, routine maintenance, security, essential changes.
Operational Cost	Energy costs, water and waste, leases, cleaning insurance.
Life-cycle Cost	Initial constructions costs, cost of operating, maintenance and repairs, replacement costs, alterations demolition.
Operational Management	Booking and space allocation systems, user support systems, help desks, manuals, training.

USEtool is an evaluation methodology that in contrast to POE does not focus on a building's technical performance but on the usability of the building. USEtool is a quite new methodology that was developed as part of a research project in Norway (Hansen et al., 2011). The aim was to develop a tool with focus on evaluation of the effectiveness of a building, which can be used by internal FM units in large organisations to evaluate their facilities together with the users. An essential part of USEtool is a facilitated walk-through in the buildings followed by a workshop together with users. USEtool consists of 5 phases as shown in Figure 3.

Figure 3: Phases in USEtool (Hansen et al., 2011)



The study included an array of different methods for data collection selected from the methodologies of POE and USEtool and decided in collaboration with the management of the two schools. Blyth et al. (2006) present a matrix with recommended methods for different types of POE, which has been used as a guideline in our study together with the methods in USEtool mentioned in Figure 3. Based on that we have utilized the following methods:

- Initial interview with the head of school and the facilities manager at each of the two gymnasiums (Herlev Gymnasium and Falkonergården) to get general introduction to the school, available documents like drawings etc. and make agreement about the case study procedure.
- Walk-through together with the head of school and the facilities manager at Herlev Gymnasium and with the facilities manager at Falkonergården.
- Observations at each gymnasium during school hours with focus on shared spaces on 3 days at different times.
- Interviews with teachers at each gymnasium – 4 at Herlev Gymnasium and 3 at Falkonergården – besides the heads of school, who also teach at each their gymnasium. At Falkonergården one of the teachers interviewed also is responsible for planning the teaching schedules.

- Interview with the student who is chairman of the student council at Herlev Gymnasium.
- Questionnaire survey with students representing 3 classes at 3 different levels at each gymnasium filled in on-line during school hours supervised by teachers resulting in a response rate of 100%.
- Document and information studies of drawings, reports and the schools' intranet.

The main limitation of the methods, compared to what we ideally would have wanted, is that it was not possible to interview students except for the chairman of the student council at Herlev Gymnasium and that it was not possible to arrange focus group meetings and workshops with users.

4 RESULTS

4.1 Case presentations

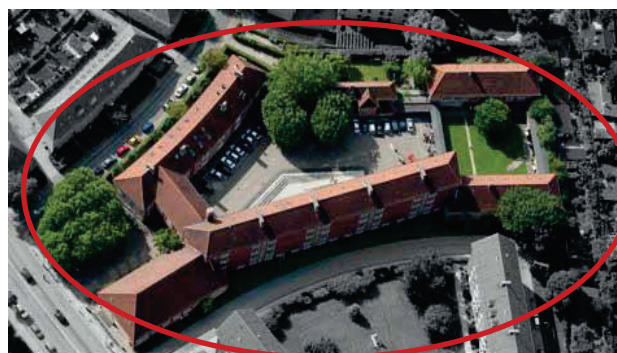
Aerial photos of the two gymnasiums are shown in Figure 4 and 5, respectively. Both are placed in greater Copenhagen, but they are not part of the Copenhagen Municipality.

Figure 4: Aerial photos of Herlev Gymnasium



Herlev Gymnasium is placed in Herlev Municipality, which covers a suburban area north-west of Copenhagen. The institution is accommodated in one building, which was finished in 1976 and designed as a typical concrete panel building shaped as a rectangular box in 2 storeys. The gymnasium has approx. 800 students and a staff of approx. 110.

Figure 5: Aerial photos of Falkonergården



Falkonergården is placed in Frederiksberg Municipality, which is an old urban area surrounded by the Copenhagen Municipality. The institution has several connected buildings built in 1955, but also rent space in the neighbourhood. It has approx. 1,000 students and a staff of approx. 100.

4.2 Strategic value and optimisation proposals

The case studies show that none of the two gymnasiums have managed to integrate their use of space in accordance with their overall strategic goals for the institutions. The analyses confirm that it is essential that a space optimisation process is based on the values and the strategic goals of the organisation. For Herlev Gymnasium the aim of the space optimisation was mostly qualitative with a focus on creating spaces that better can support the teaching, motivate students and teachers and attract more students. For Falkonergården the aim of the space optimisation was mostly quantitative with a focus on an increase of the utilisation of existing spaces to accommodate an increasing number of students but also if possible to avoid rented space outside the school buildings.

Besides defining the purpose and clarifying the specific conditions at the institution in question it is also important that the space optimisation project includes an analysis of the less concrete aspects like the culture and the habits of the users, which can be crucial in developing specific proposals for optimisation. A holistic approach and an all-round insight can ensure that the proposals are not only based on a superficial and theoretical understanding but that the proposed solutions after implementation really create the added value that is demanded. Both aspects can be revealed by involvement of the users in the process. This can also help to ensure that the optimisations do not improve some aspects at the expenses of others.

The project resulted in 11 proposals for space optimisations at Herlev Gymnasium and 7 at Falkonergården. Even though the purpose of the space optimisations and the layout of the existing buildings are very different for the two institutions, there are also some striking similarities:

- A lack of development of the school buildings in relation to changes in the teaching activities that takes place in the building, including an increasing use of group work
- Limited and insufficient spaces dedicated for teachers to prepare
- The possibilities to make quantitative space optimisation are limited

We do not know whether these problems are general for other gymnasiums in Denmark, but we hypothesise that many other gymnasiums in older buildings face similar problems as Herlev Gymnasium and Falkonergården.

4.3 POE and USEtool

POE has contributed to specify which aspects should be included in the analyses, including most importantly the first four in Table 2: Strategic Value, Aesthetics and Image, Space, and Comfort. These aspects have helped to make the results from the two schools comparable to some degree. POE has also contributed with specific procedures to be used in the analyses and made it possible to relate the space optimisation to the people using the spaces and who eventually will be affected by an implementation.

USEtool has contributed to give structure to the evaluation and to put focus on the users of the spaces. USEtool have provided a useful overall frame for the process. The focus on in-

volving the users has given the analysis multi-sided aspects, which has helped to provide a holistic analysis of all relevant aspects in the space optimisation.

The study has revealed a number of advantages and drawbacks of both methodologies. An overview of these is shown in Table 3.

Table 3: Advantages and drawbacks of POE and USEtool

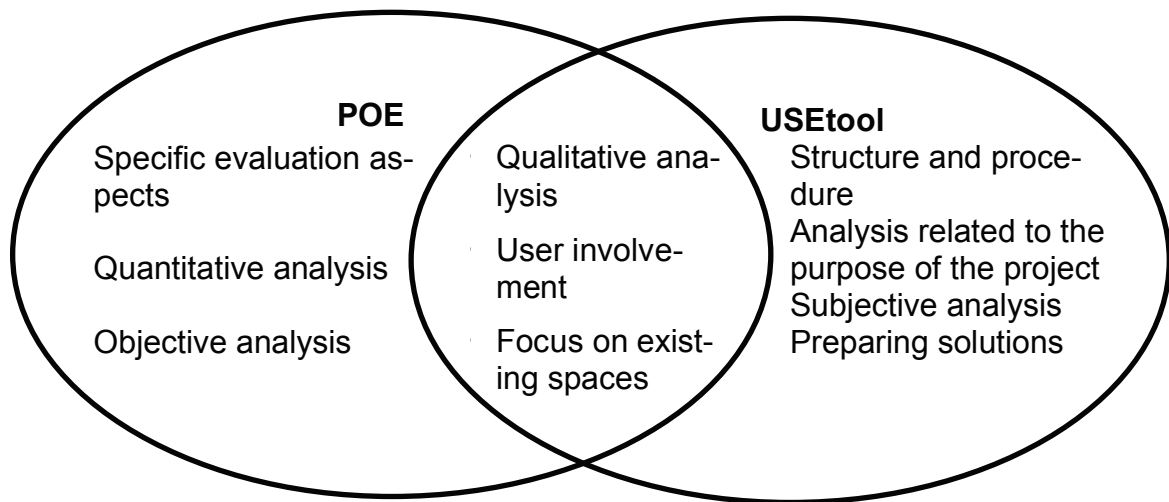
	Advantages	Drawbacks
POE	<ul style="list-style-type: none"> • Includes many different aspects which all are seen as relevant in relation to space optimisation • Several methods can be used to conduct the analyses • Works well as a checklist to cover many important aspects 	<ul style="list-style-type: none"> • The lack of structure (freedom of choice of methods) makes it difficult to decide the optimal procedure of the analyses • There is no clear definition of which users that should be involved in the analyses of the different areas • Only to a limited degree presents concrete procedures in relation to interviews, questionnaires, observations etc.
USEtool	<ul style="list-style-type: none"> • The methodology solely focuses of the needs and wishes of users, which is seen as relevant considering that the space optimisation mostly affects the users • USEtool is a structured methodology which clearly describes the procedure of the analyses • USEtool is flexible and can be adapted to the organisation in question • USEtool encourage to involve several different groups of users 	<ul style="list-style-type: none"> • It cannot be taken for granted that the users are capable of evaluating the usability of a building • The perception of the usability of a building can be very subjective, which makes it difficult to generalise the different views in a group of users • Based on our experiences from the two case studies the phases in USEtool do not seem to be optimal • USEtool does not call for iterations between the different phases, which we found would be favourable • It takes a lot of effort to adapt USEtool to the specific organisation in question

Among these is that POE functions as an efficient check list, which ensures that all the essential aspects are included in the evaluation of existing spaces. The lack of structure in POE on the other hand makes it difficult to decide in which order the analyses should be carried out.

One of the advantages of USEtool is that it helps structuring a space analysis and at the same time involves different stakeholders, which ensures an all-round analysis. One of the pitfalls of USEtool is that if the user involvement is not handled appropriately it may create a false picture of the actual situation. Furthermore, the division in phases in USEtool does not seem optimal from our experiences and the methodology in the present form does not call for iterations between the different phases, see section 4.4.

The two methodologies complement each other as POE defines relevant aspects for the analysis and USEtool contributes with a structure to the analysis. Thus, we find that a combination of the methodologies creates a synergy effect compared to using the methodologies individually. Figure 6 illustrates how the two methodologies diverge and overlap.

Figure 6: Divergences and similarities between POE and USEtool



4.4 Proposal for a new procedure

Based on experiences from the two case studies and the combined use of POE and USEtool as a basis for data collection, space analyses and proposing space optimisations we have developed a proposal for a new procedure for space optimisation in HEI. The procedure includes 7 phases, which are described in Table 4. The first phase is crucial to frame the project in relation to the specific organisation, the strategic situation and defining the purpose together with the school management. For the project to add value it is essential to define which kind of value the project should aim at. This is suggested to be specified in a number of success criteria.

The procedure includes both qualitative and quantitative data collections with an extensive involvement of the primary stakeholders covering teachers and students as users. This covers interviews, observations, focus groups, walk-throughs, questionnaire surveys and workshops. The project is expected to result in proposals for both qualitative and quantitative space optimisations.

USEtool only includes one walk-through, but in the new procedure we have included two walk-throughs in different phases. In the start of the project the new procedure in phase 1 includes a walk-through, which supports a visual introduction to the buildings with some of the stakeholders (head of school and facilities manager) and later in phase a walk-through with the primary stakeholders (teachers and students). We find this important as the “two” stakeholders groups most likely have different views on the space utilization. Furthermore, USEtool does not include a phase which allows a larger group of stakeholders to get involved in the space evaluation which the new procedure includes as questionnaire survey(s) in phase 5, which can involve separate surveys for students and teachers.

5 PRACTICAL IMPLICATIONS

The research provides examples of how value adding space optimisation processes can be undertaken in HEI by using a combination of different methods and extensive user involvement. Based on two case studies utilising a combination of the methodologies POE and USEtool it proposes a new procedure for space optimisations. The procedure can be used by the

management of HEI and by consultants for HEI. The procedure can also give inspiration for space optimisation in other types of organisations.

Table 4: Proposal for a new procedure for space optimisation in HEI

Phase	Objectives	Activities
1	Clarification of purpose and success criteria Identifying stakeholders Preparing project plan and clarify resources Collection of data about the organisation, the buildings and space challenges	Interview the head of school and the facilities manager Walk-through with the head of school and the facilities manager
2	Collection of data about use of space	Observations and interviews Analyse space utilisation
3	Discussions about the existing use of space	Focus groups with the primary stakeholders
4	Clarifying which space solutions work well and not well – generally and related to specific aspects of the analysis	Walk-through with the primary stakeholders
5	Involvement of a larger groups of stakeholders	Questionnaire survey
6	Preparation of proposals for space optimisation and implementation plan	Workshop with the primary stakeholders, the head of school and the facilities manager
7	Implementation of space optimisations	Churns, rebuilding etc.

6 CONCLUSION

Space optimisation should be regarded as a complex activity which cannot be characterised by one correct procedure or with only one right solution. To create added value it is necessary that the space optimisation focus on exactly the aspects relevant for the specific organisation, its strategy and circumstances that define the purpose of the project.

The case studies showed that both gymnasiums lack a development of the school buildings in relation to changes in the teaching activities that takes place in the building, including an increasing use of group work. Many other Danish gymnasiums in older buildings might face similar problems.

Several space optimisation initiatives that could lead to improvements in space utilisation as well as in the learning environment were identified. The study combined the methodologies POE and USEtool and provides a critical assessment of these methodologies. The methodologies complement each other. A new procedure for space optimisation in HEI is proposed including a structured combination of aspects included in POE and USEtool.

The research is based on two case studies on Gymnasiums in Denmark, which limits the possibility to generalise, and the new proposed procedure for space optimisation in HEI has not been tested.

REFERENCES

- Blakstad, S.H., Olsson, N., Hansen, G.K. and Knudsen, W. (2010), *Usability mapping tool*. In: Alexander, K. (ed.) (2010), *Usability of Workplaces - Phase 3*. International Council for Research and Innovation in Building and Construction - CIB.
- Blyth, A., Gilbyand, A. and Barlex, M. (2006), *Guide to Post Occupancy Evaluation*. Higher Education Funding Council for England (HEFCE).
- CEN/TC 348 (2006): *Facility Management – Part 1: Terms and Definitions*. EN 15221-4.
- Che Ani, A.I., Tawil, N.M., Musa, A.R., Tahir, M.M. and Abdullah, N.A.G. (2012), *Frequency Index for Learning Space in Higher Education Institutions*. *Procedia - Social and Behavioral Sciences* 56(2012) pp. 587-593, Elsevier.
- Downie, M. L. (2005), *Efficiency outcomes from space charging in UK higher education estates*. *Property management*, Vol. 23 Iss: 1 pp. 33-42, Emerald.
- Earthman, G. I. (2004), *Prioritization of 31 criteria for school building adequacy*. American Civil Liberties Union Foundation of Maryland.
- Fronczek-Munter, A. (2013), *Evaluation methods for hospital facilities*. Dansk Facilities Management 2013. 12th EuroFM Research Symposium.
- Hansen, G.K., Blakstad, S.H. and Knudsen, W. (2011), *USEtool - Evaluating Usability - Methods Handbook*. NTNU.
- Hasbullah, A., Yusoff, W., Ismail, M. and Vitasari, P. (2011), *A framework study of school facilities performance in public primary school of Butubara district in Indonesia*. *Procedia Social Behaviroal Sciences* 15 (2011) 3708-3712.
- Ibrahim, I., W. Z., Yusoff, W. and Sidi, N.S.S. (2011), *Space Charging Model: Cost analysis on classrooms in higher education institutions*. *Procedia - Social and Behavioral Sciences* 28 (2011) pp. 246 -252, Elsevier.
- Ibrahim, I., W. Z., Yusoff, W. and Bilal, K. (2012), *Space management: a study on space usage level in higher education institutions*. *Procedia - Social and Behavioral Sciences* 47 (2012) pp. 1880 -1887, Elsevier.
- Jensen, P.A., van der Voordt, T. and Coenen, C. (eds.) (2012), *The Added Value of Facilities Management. Concepts, Findings and Perspectives*. Centre for Facilities Management – Realdania Research. Polyteknisk Forlag.
- McGregor, W. and Then, D.S.-S. (1999), *Facilities Management and the business of space*. Wiley.
- Kuuskorpi, M. and González, N. C. (2011), *The future of the physical learning environment: school facilities that support the user*. CELE Exchange 2011/11. OECD.
- Mei-yeung, L. and Fung, I. (2005), *Enhancement of classroom facilities of primary schools and its impact on learning behaviors of students*. *Facilities*, Vol. 23 Iss: 13 pp. 585-594, Emerald.
- Mosbech, K. (2004), *Workspace. Organizational Goals and Physical Environments*. Litotryk Svendborg as.
- Ornstein, S., W., de Andrade, C.M. and Leite, B.C.C. (2005). *Assesing Brazilian workplace performance*. in: Preiser, W. F.E. and Vischer, J.C. (eds.) (2005), *Assessing Building Performance*. Elsevier.
- Tinsfeldt, M. (2013), *Arealoptimering og Brugerinvolvering*. DTU Management Engineering.

9.4

**USABLE AND AFFORDING PHYSICAL AND VIRTUAL
LEARNING ENVIRONMENTS**

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ABSTRACT

Purpose: This paper aims at identifying the key characteristics of both physical and virtual learning environments and their affordances. The research question is how active and social learning processes can be supported by the physical, social and virtual environment.

Background: The study integrates the pedagogical cyclic *Engaging Learning Environment* model with the *USE frame* model of usability of built environment in order to transfer the user experience of content of use and to create new knowledge in order to increase usability of the learning environment.

Approach: By a qualitative in-depth study of user experiences of Living lab Minerva the paper contributes to the field of user-based spatial and technological design and refinement of learning environments. The underlying proposition is that a thorough analysis of user experience provides valuable data for developing future embedded learning environments and affordances related therein. A group of ten teacher students was observed in the process of seven weeks' dynamic and group-oriented project work. Observational data and interviews were gathered and analysed throughout the project.

Results: The value added characteristics emerging from the shared use of interactive participatory methods (e.g. Flinga® – program for knowledge co-creation) were stressed in relation to the use of space as well as in terms of how the physical space and its affordances were experienced, also in different ways among participants.

Practical implications: The results are used in the development of usability methodologies for participatory design processes for future built environments.

Research limitations: The living lab circumstances are limited to the technology embedded in the investigated space and it sets some limitations in terms of generalizability.

Originality: The data gathering has taken place in a living lab demonstrating an early phase of embedded learning environment.

Keywords: Embedded learning environment, Living lab, Usability of learning environments, User participation, Physical and virtual space, Knowledge co-creation

1 INTRODUCTION

The development of ICT (information and communication technology) and digitalization alter our activities and almost every space from working, studying, and teaching to leisure. In terms of learning environments the actual learning can happen both virtually and physically, which makes it more complicated to plan the physical spaces (Dugdale 2009). The research, which aims to extend understanding about usability, as applied to buildings and support services, has focused on learning environments in the last years. School facilities should be considered in the context of the communities they serve, and as a prime means of transforming education (Alexander 2009).

The educational transformation is led by a variety of changes in learning practices such as increasing understanding of the fact that the majority of learning takes place outside the classrooms. Social interaction is a growing part of learning, and pedagogy is shifting towards collaborative methods as students are motivated by social interaction. Learning can occur out of sequence, as students are comfortable with overlapping discussions and new learning tools with respect to the traditional tools. Students construct rather than just consume knowledge – this is partly because of easy-access technological tools and easy-to-spread on-line platforms (Milne 2006).

This paper aims at identifying the key characteristics of both physical and virtual learning environments and their affordances. The research question is how active and social learning processes can be supported by the physical, social and virtual environment. By an in-depth study of user experiences of Living lab Minerva the paper contributes to the field of user-based spatial and technological design and refinement of learning environments.

2 LEARNING AND USABILITY OF LEARNING ENVIRONMENTS

The study integrates the pedagogical cyclic *Engaging Learning Environment* model (ELE) (Lonka, 2012; Lonka & Ketonen, 2012) with the *USE frame* model of usability of built environment (Lindahl et al., 2011) in order to transfer the user experiences in the context of physical and virtual learning environments to new knowledge of usability of the learning environments. In educational sciences, e.g. the blended learning environments are an increasing type in the future. They combine physical, virtual, social, mobile and mental spaces of learning (Lonka, 2012; Lonka & Ketonen, 2012). This fact is identified also in usability of learning environments, where they are defined as the socio-psychological, physical and digital settings, in an organisation or community context, in which learning occurs and which affects learners' achievement and attitudes (Alexander, 2009). Effective learning environments suc-

cessfully combine appropriate social and digital environments with the physical environment (Beard, 2012).

Usability of built environment is an intriguing challenge for architects, designers and facilities management (FM) as it concerns how a space, an artefact, is used and the effects of that use. It is an equally challenging concept for managers and organisational strategists as it includes the physical setting in which an organisation performs its activities. This makes usability of facilities a topic at the centre of the relationship between what we do, how we do and where we do it (Alexander 2009). According to Fenker (2008) usability in the built environment is context dependent, a product of user experience related to the social relations amongst users and to the interaction between users and facilities.

The UseFrame model aims to conceptualize contextual dimensions of usability. It illustrates steps in a process of understanding and mapping use to support action in design and construction projects or FM processes of maintaining the facilities. UseFrame can be used to describe processes, where clear information, participation and knowledge dissemination are beneficial (Hansen et al., 2010; Lindahl et al., 2012). The latest educational innovations are based on the notion that meaningful learning, aiming at conceptual change and understanding, is most likely to develop in meaningful social interaction. Student-activating and engaging learning (ELE) is a current pedagogical model that consists of the following three key cyclical stages (Lonka, 2012):

Stage 1: Diagnosing and activating current understanding and knowledge; the interest is awoken, and the need for learning is diagnosed along with goals for the learning process.

Stage 2: Fostering the learning process and reflective thinking; interest is promoted and maintained, and the process is supported with different tools (applications, technology) and methods, and the level of interest is deepened on the net, P2P, at home, etc.

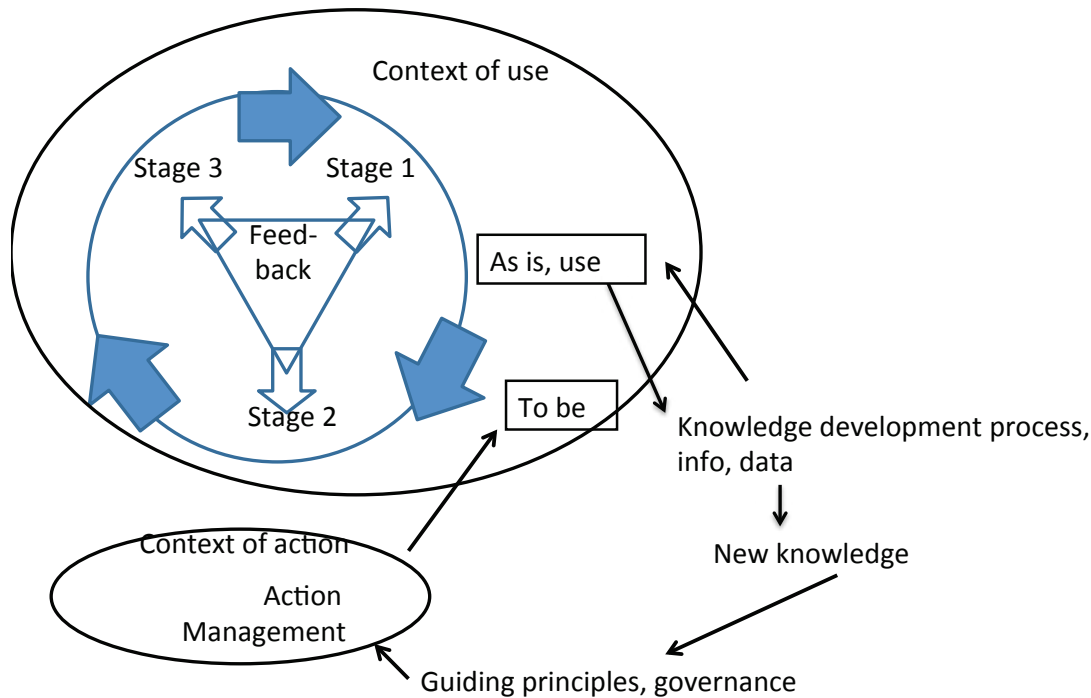
Stage 3: Assessing change and giving feedback; the following questions help in diagnosing how the process worked out: What was learned? What new was created? How did the process proceed? The level of interest is strengthened by group discussions.

These stages of the learning process create the context of use and the requirements of physical and virtual environments are designed and built to be learning environments – the user experiences shade the light to the facts how the facilities are as used (Figure 1). This information is important to knowledge development of usability of learning environments. The individual and group behaviour in embedded learning environments require more evidence-based proof – not only for the usability of complementing learning environments, but also for the processes to co-create them (Lonka, 2012; Lonka & Ketonen, 2012).

This study focuses on living lab context in terms of learning environments, where the process itself is based on new pedagogical thinking and the platform for enhancing it is both physical room and virtual, interactive interface. The limited context of living lab provides a possibility to focus on adaptive and flexible learning environment which is supporting the active and collaborative learning process. This research is focusing on learning processes in environments that are embedded by nature. The basic assumption of the process is that they are collaborative (sense of community; use of co-creation platforms), and activating (empower-

ment). The steps taken in the learning process are also taken on the physical and virtual platforms, which are adaptive.

Figure 1: The ELE-model as context of use in USE frame for developing usability



3 METHODOLOGY

3.1 Sample

The qualitative approach and interviews in the context of actual use of embedded learning environments are the appropriate way to achieve data from user experience. The participants were ten ($N=10$) with educational psychology as a major in class teacher students at the University of Helsinki, Finland. Data collection took place when the students were in their second year of a five-year Master's program. The participants were aged between 21 and 35 years; nine were female and one was male. The observed group of ten students follows an inquiry-based curriculum in the lines of the Engaging Learning Environment (ELE) model.

The studied group has worked intensively together in their ten-student group for the first three years of their bachelor's studies, after which they specialize and finish their master's studies. By partaking in the same courses, lectures and group work sessions. Studying this kind of a ten-student unit who have already spent the first one and a half academic years in the same group possibly provides the researchers with a more cohesive and collaborative set of students than would be the case with any other random course with changing students.

Students designed, implemented, and evaluated in iterative reflective cycles a study unit that they collaboratively named “Innovation in the City”. They adopted a multidisciplinary perspective, integrating the disciplines of Geography and Crafts. During this study unit, the students agreed on planning and organising the course and the contents with a special focus on their own learning processes, as opposed to practical application of the study unit’s output in their possible future jobs as class teachers in elementary schools. The teacher students worked collaboratively with university lecturers and approached their inquiries from multiple perspectives. However, the students met the university lecturers only approximately 6 times during the ca. 30 sessions they had. In addition, the lecturers met the students individually four to five times during the study unit. Altogether, these different ways of working gave the students a chance to engage in a dialogue and exchange of opinions with varying members of their study community.

The students conducted both individual and co-creative between-sessions tasks including searches for scientific information, accustoming to journal articles, and writing essays. The results of these tasks were then discussed in both the student group and with the lecturers. At the end of the project, an evaluation panel session was held in which the students and teachers together discussed and agreed on a common grade for the whole group.

3.2 Data Collection

Before the collection of data for this study, the students filled in an informed consent form giving permission to use all the material that they produced for research purposes. These included the recordings, observations, interviews, questionnaires including questions about situational academic emotions and interest, and their own material that they produced during the whole study unit (including the weblog they kept, the pictures they took to form a path of emotions and flow, and all other possible excerpts that they produced).

In mutual consensus, only some of their sessions or parts of them were researcher-free, i.e. the students told the researcher beforehand if they would want to start a session without external observers due to personal matters or discussions that were experienced intimate to the group members. In this study, we delimit our focus on application of the pedagogical background theory in the students’ work and their reports on the usability of the learning environment and the use of technological affordances and tools as reported by the participants in the interviews and as observed by the researchers during the study unit.

In this study, we delimit our focus on application of the pedagogical background theory in the students’ work and their reports on the usability of the learning environment and the use of technological affordances and tools as reported by the participants in the interviews and as observed by the researchers during the study unit.

The interview materials were collected in a semi-structured fashion during the 7-week intensive period of inquiry-based group work. The study was composed using questions that regarded 1) the positive and negative experiences during the group work, 2) the pedagogical and instructional setting of the study unit, 3) the use and applicability of affordances and technology (including explicitly the tablet computers that the students have been given by the faculty responsible for their major subject in educational psychology), and 4) the usability and functionality of physical spaces during the study unit. The interviews were performed immediately after the final panel session that the group of students organised to be participat-

ed by all interested parties including their teacher trainers and other students as well as the researchers.

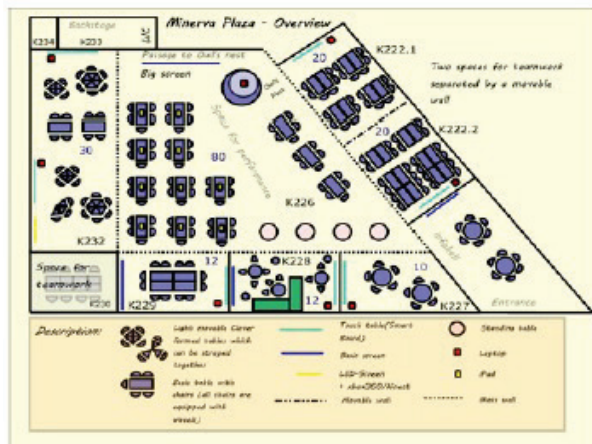
The interview recordings were transliterated and analysed by the researchers with a special focus on the feedback and responses they reported in relation to the four semi-structured themes mentioned above. This study was performed as an intensive collaboration between scholars from both behavioural sciences (especially educational psychology) and facilities management research and architecture. The approach is an intertwined process in which all the mentioned branches of research are central.

The present study took place between 12th March and 2nd May, 2013. During this period, the students also participated in various subject matter-based courses in the teacher-training program, including for instance Curriculum studies and development, Music education, and Scientific writing.

3.3 Living Lab Minerva Plaza

Minerva Plaza, the living lab environment in the University of Helsinki, is structured and organised so that it promotes the parts of this process in a way as optimal as possible. The central plaza (see Picture 1 for an overview of the studied environment and a close-up picture of the plaza) works well for the first stage of diagnosing the current understanding and knowledge.

Picture 1: Overview of the Minerva Plaza



The furniture is movable, and social interaction can be organised in a vast variety of ways also physically (see also <http://vimeo.com/60818003> for a two-minute video showing different physical settings in Minerva over a period of one month). The group workrooms that are adjacent are designed to function as arenas for the continuous learning process along this cycle. The students may also continue their study process individually or collaboratively outside university or on-line.

In Minerva, the students are readily able to use the Finnish Flinga application. It is a collaborative, co-creative platform intended for knowledge building and easiness of participation (see <http://www.nordtouch.fi/>). Flinga builds on *bring your own device* (BYOD) thinking. The receiver (laptop or regular PC/Macintosh) is the only device that must have the application downloaded. The participants in a given session use their own devices to contact the

Flinga application via browser-based HTML5 sender. Text, pictures and drawings can all be sent, and in the end, organised on e.g. an interactive white board. Flinga enables the users to partake in the knowledge-creating sessions anonymously. In the studied group of class teacher students, the students have been given iPad tablet computers by the project, with an aim to be able to study their use of interactive applications, technology, and the ways technology can be integrated into engaging learning and learning environments in a constructive way.

The Living lab area used to be a library of the department in University of Helsinki. The renovation to the new use of space was challenging due to the structure of the space.

4 RESULTS

The interactive technological applications that were afforded by either the space in which the group gathered or by the mobile devices used by the group members were discussed oriented by the interview questions. However, the specific applications were saliently brought up by the interviewees and strikingly, on many occasions before these topics were taken into discussion by the researcher.

4.1 Social place

The value added characteristics emerging from the **shared use of interactive participatory methods** (especially Flinga) were stressed in relation to the use of space as well as in terms of how the physical space and its affordances were experienced. One student reported the **beneficial anonymous aspect** about using Flinga, although she also referred to the "pseudo-innovativeness" of such technology:

"I have a love-hate relationship with Flinga because I'm still not quite sure whether it's something really new, because people have always like written things down together and brainstormed whether it was on a post-it or on a chalk board... that it's not new as an idea... but still I've got to give in for Flinga just a bit because... it's like it enables a sort of more fluent brainstorming, and that way a more productive brainstorming session as it's so easy".

In Picture 2, one of the students is organising the brainstorming data sent to the interactive whiteboard by the rest of the group. Most sessions had a chairperson who was responsible for giving turns for spoken commentaries, organising the schedule, and e.g. organising the data produced by the group.

Picture 2: Hands-on knowledge co-creation during the study unit



The study unit and the curriculum that the students follow include a lot of reflection on one's learning and group-work abilities, etc. In the end of one of the interviews, when asked about anything that the informant might have felt he or she still had something to say about, she stated that,

But what I could add is that using that Flinga in reflection is really like... it makes it considerably easier. And somehow like... it doesn't require the group to listen to one member at a time as like... then the ideas are shared there [on the Smartboard] and it obliges one to kind of crystallise one's thought. [---] Also, saving such a reflection discussion is next to impossible. One could of course transcribe recordings of the sessions but who is there to like do it, and no-one loses parts of the reflection when they have to concentrate on writing down everything. In that sense it's also like very good. Easy to use I mean a practical tool.

4.2 Embedded place

The mobility and experienced timelessness and placelessness of using mobile devices, like the tablet computer, became an empowering experience for most students. One of them recalled how she at first did not quite know how to use the tablet, and eventually found herself so accustomed to using it that being without it almost became something that she cannot picture:

At first, I thought they were of little use for us... that it took its time to become accustomed to using it and to find one's own routines in using it. And now that I've found the routines and become familiar with the tablet and know how to apply it, now I'm at point where I wonder how I ever managed without it. That it's the finest thing about it that it doesn't tie you to a certain time and place, but as it's a small thing to carry with you, it's always with you right there and it like helps tremendously in a student's mundane life...

Combined with the tablet computer provided by the faculty, one student reported about the easiness of contribution that both the tablet and Flinga provide:

... Our collaboration is more interactive and like one can more widely participate and contribute to the common activity, because if it's one of us that just writes at the computer like a secretary, or when we discuss in turns, what it always does is that before your turn comes there have been like nine other points of view.

The **instability** still present when using wireless digital technologies is an aspect that, for its part, raises questions and criticism. A point laid out by one student is that the easiness of accessibility and usability of new technology is a key requirement for these new technologies to really enter school and other contexts:

... There's still the problem that when the technology coughs just a bit, then the way towards using it becomes too long. I mean that in order for them [technologies] to really be implemented there [at school] and to be used creatively and in a way that really consequently supports the work done there, it should be so secure to use that when you start the program and say "Let's use Flinga", then you go on and use Flinga! And not like that it takes two thirds of the lesson when the teacher doesn't really know, that "this is not working, and that "let's wait for the ICT support"...

4.3 Virtual place

The easiness of use of the technological tools that are being tested in the living lab gained much positive attention. Although the group members work with their team quite intensively and learn to know each other rather well - compared to random groups that do not collaborate as intensively as the group that we observed - they still report many contexts where the interactive tool that enables anonymity comes in handy and gives an opportunity to co-create without always proceeding one after another. This also increases instances of true brainstorming without being interrupted by turns taken by each group member at a time. This amounts to the application's quickness, fluidity and spontaneousness. It also increases equal opportunities to participate and co-create. When the tool becomes familiar, it also becomes safe to use and quick, and one does not necessarily have to formulate each thought and idea precisely; the innovation-promoting features of the application were expressly stated one student.

"The technological applications here they are like... they make things easier. Like Flinga, it's just like... it's like a time-saving way to go through the brainstorming sessions that would normally take lots of time and energy."

4.4 Physical place

The flexibility of the space was stressed in many responses in the final interviews. The technological pedagogical intertwining of new tools with the physical space was explicitly present in most respondents' reports: some of them even described how they could no longer picture themselves doing collaborative tasks and participating in collaborative learning without the use of e.g. Flinga - and it can for the time being only be used in given spaces, delimiting the possible positive affordances provided by spaces that do not allow its use.

A positive feature of the Minerva living lab reported by the students is its **true flexibility** as to for instance furniture. When performing collaborative group tasks, the students might change the position of chairs and tables as they wished. This was particularly important at times of utter brainstorming and relaxation in between. In addition, many students feel that tables between people - at least if not movable - hinder co-creation and reciprocal communication, and they were even ready to remove the tables completely. When asked about experiences of different physical spaces during the study unit, one student reported:

Well I've got to admit that for the most part, I don't understand why people sit with a table in between them. [---] Like in a way, when we think about school world, then they are like... the spaces don't support knowledge building and interaction.

Another student reported the same when asked about the tables. The **effortless movability** of the tables in the living lab was seen as something truly positive, although the existence of tables in the spaces was found to have an affinity in people:

But these tables like invite one to sit around them as one's always done before. [---] Well like at times it feels like the table isn't a good thing. That at times we've like been here sitting in a circle when reflecting more on something, like something that requires more thinking effort that everyone doesn't have to write down on the tablet or read something, that it's been quite refreshing just to concentrate together on the idea.

The physical space, i.e. in most cases, the Minerva living lab, was experienced by the students as an **empowering and positively exciting learning environment**. When asked about the different seminar rooms and learning environments, one of the students reported that,

Well, generally, I feel it's wonderful that we have these like... or that I feel we're privileged to have these kinds of nice comfortable spaces where we can be. And these are especially suitable for small groups that the few times we have been in those more traditional classrooms they aren't in a way comfortable environments. At their worst we have been eight hours in a classroom with no windows.

Another pointed out the fact that they actually felt **attachment and agency in the living laboratory** due to the flexibility of the space and the movability of the tables and furniture. She also mentioned the tall glass walls that divide the central plaza from the smaller group work rooms around the plaza (see picture 1 for an overview of the living lab).

Over there in the smaller room the tables there are nice, they are smart and at times we have done so that we have sat on the floor and then people have stared at us from the plaza (laugh)... I really like the big glass walls.

The physical affordances intertwined with the technological possibilities seemed to become an **element in the students' study strategy**. According to field notes of observed behaviour, the students seemed to adapt the contents of each session partly with regard to the space that they would work in. For instance, the technological tools available at the Minerva Plaza living lab were not achievable in seminar rooms with little or no technology. In one of the other seminar rooms with e.g. no windows, the students performed more improvised parts of the study unit, for example a drama exercise. On the other hand, this may also have been due to too much transparency in the spaces surrounded by glass walls at the living lab, and some functions may be experienced too intimate to be performed so that everyone can see what happens.

4.5 Summary of the results

To sum up the results one can identify eight elements for usable embedded learning environments (Table 1).

Table 1: Usability factors of embedded learning Environments

USABILITY OF FACTORS	LIVING LAB AS USED	
	ACTIVATING	COLLABORATIVE
SOCIAL PLACE	Space set ups according to the context of use, feeling of agency ownership.	Forming the space according to the context is a social process.
EMBEDDED PLACE	Both physical and virtual environments are agile, fast, flexible and instant.	The physical and virtual environments increase the sense of democracy.
VIRTUAL PLACE	Interactive virtual interface, Flinga makes it easier to contribute: it is an easy interface and the content is easy to co-create.	Interactive interface is a shared tool and increases the sense of community.
PHYSICAL PLACE	The learning environment is flexible and dynamic – it is easy to vary between places, also embedded.	The learning environment is familiar and safe, which increases empowerment and attachment.

6 PRACTICAL IMPLICATIONS

The results can be applied both in assessing and developing usability of the new kind of embedded learning environments. The flexible and embedded learning environments can support the social processes both in process itself as well as in tuning the environment. The identified elements e.g. physical and virtual flexibility, easiness of use, socially constructed environments; adaptive affordance and democracy can be used for criteria to development and design of modern learning platforms, which are embedded.

7 CONCLUSION

The views that were found in the students' reports about their use of space and technological affordances therein were rather unanimous in nature. However, the student population studied here represents a small minority within the behavioural science students overall, and follow a curriculum that differs markedly from the general curricula. This way, this study describes the experiences of a well-selected subpopulation, and we cannot know how other students vary in their reports in relation to the living laboratory.

Parts of the usability of the spaces and technologies in the studied environment seemed to form an adaptive continuum. Having started the study unit in embedded spaces where Flinga and other interactive technologies and applications for knowledge co-creation and co-design, the students may have adapted their behaviour and study strategies in relation to the space they would use for each content. The firstly experienced flexibility of the living lab cannot be transmitted into all spaces, and thus certain functions require certain facilities. On the other hand, certain spaces do not afford certain activities, and this may in a way be taken advantage of by adapting the activities according to the spaces flexibility and potential. This kind of behaviour might even be called "smart usability" or "adaptive usability".

In the future, we aim at deepening the understanding by analysing in depth the video-recorded materials and seeing how different student profiles work in the space. This is done by combining large quantitative data to our present group-work data and by combining a given profile to the student working in the group. This way, we can profile the collaborative ways of being of the students. The Minerva Plaza Living Lab is in a continuous process of emergent ways to use it as a learning space and as a physical setting for interactive use of technologies.

As a forerunner case Living lab Minerva, in its dynamic evolving processes, is intended to simulate the world of schools 2020, "School 2020", and the emerging technological affordances are being tested in the space all the time. The results will eventually be used in creating new constructive ways of using and designing not just the Living lab Minerve but also, more broadly, learning environments in different schools, where at least some of the studied teacher students will most probably work in the future.

ACKNOWLEDGEMENTS

This work was supported by the RYM Indoor Environment project 462054 funded by the Finnish Agency for Technology and Innovation (TEKES).

REFERENCES

- Alexander, K, (2009), Usability of Learning Environments, CIB W111 Research Workshop, Gothenburg, April 2009.
- Alexander, K, (2010), The usability of learning environments, in *Usability of Workplaces—Phase 3. Report 330*. Rotterdam: CIB.
- Alexander, K, Blakstad, S, Hansen, G, Jensen, PA, Lindahl, G and Nenonen, S (2013), 'Usability: managing facilities for social outcomes'. in S Kajewski, K Manley & K Hampson (eds), *Proceedings of the 19th CIB World Building Congress 2013: Construction and Society*. International Council for Research and Innovation in Building and Construction (CIB). http://www.conference.net.au/cibwbc13/papers/cibwbc2013_submission_338.pdf. Site accessed 17.11. 2013.
- Beard, C, (2012), Spatial ecology: learning and working environments that change people and organizations. In: Alexander, K. & Price, I., (Eds.), *Managing organizational ecologies: space, management and organization*. New York: Routledge, 69–80.
- Dugdale, S. (2009). Space strategies for the new Learning landscape. *Educause review* , 51-63.
- Fenker M (2008) Towards a theoretical framework for usability of buildings. In Usability of Workplaces, Phase 2. CIB W111 research report.
- Hansen G., Olsson N. and Blakstad S. (2010), Usability Evaluations – User Experiences – Usability Evidence. In: *CIB Proceedings: Publication number 336*. CIB W70 International Conference in Facilities Management. “FM in the Experience Economy”, pp. 37–48.
- Lindahl G, Blakstad S.H., Hansen, G.K. and Nenonen S (2011). USEframe – A framework to understand and map usability research. In *Proceedings of the 6th Nordic Conference on Construction Economics and Organisation*.
- Lonka, K. (2012) Engaging Learning Environments for the Future: The 2012 Elizabeth W. Stone Lecture. In Gwyer, R., Stubbings, R. & Walton, G. (Eds.), *The road to information literacy: Librarians as facilitators of learning*. IFLA Publications Series 157. Berlin/Munich: De Gruyter Saur, 15–30.
- Lonka, K. & Ketonen, E. (2012) “How to make a lecture course an engaging learning experience?”, *Studies for the Learning Society*, 2–3, 63–74.
- Milne, A. J. (2006). Designing blended learning space to the student experience. In D. Oblinger (Ed.), *Learning Spaces (Vol. 2)*. Washington, DC: Educause.
- Peacock, A. & Pratt, N. (2011) “How young people respond to learning spaces outside school: A sociocultural perspective”, *Learning Environments Research* 14, 11–24. Routledge.

<http://vimeo.com/60818003>

<http://www.nordtouch.fi/>

CHAPTER 10

FM INNOVATION AND TECHNOLOGY

10.1

Big Data as Innovative Approach for Usability Evaluations of Buildings

Nils Olsson, Heidi Bull-Berg and Antje Junghans

10.2

Tools for Stakeholder Involvement in Facility Management Service Design

Giulia Nardelli and Ada Scupola

10.3

Identifying Concepts for Studying Implementation of Information Technology in Facilities Management

Poul Ebbesen and Sten Bonke

10.1

**BIG DATA AS INNOVATIVE APPROACH FOR
USABILITY EVALUATIONS OF BUILDINGS**

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ABSTRACT

Purpose: The purpose of this paper is to investigate how Big Data can add a new dimension to usability evaluations of buildings.

Background: There is a tremendous growth in the volume of available data, creating the “Big Data” trend. Industries such as IT, retail and transportation can present a number of examples of successful applications of Big Data. Usability has traditionally been analysed by qualitative research methods, and Big Data gives an opportunity to add quantitative data in such evaluations.

Approach: The study is based on literature research and interviews with 15 professionals in IT facilities management and government agencies. We discuss potential data that can be used for usability evaluations of buildings.

Results: Big Data is creating new opportunities to analyse a phenomenon based on different types of data. Interesting data categories include: internet traffic, movement-related data, physical environment data, typically from different types of sensors and commercial activity. Possible problematic issues related to use of Big Data are availability, applicability, relevance, privacy policy, ownership, cost and competence. The study indicates that none of the challenges need to hinder use of Big Data when evaluating the usability of in buildings evaluation, provided that the issues are properly managed. We present a sample of Big Data that may be used for evaluation of building usability.

Practical Implications: Our conclusion is that there are major advantages in using Big data, increasing the opportunities for the evaluator to find indicators that are relevant to the building being evaluated. Use of Big Data can serve as a step towards a stronger technology focus in usability evaluations of buildings, and thus support innovation in building design and facilities management.

Research limitations: The research is mainly done in a Norwegian context.

Originality: We have found few previous studies that explicitly link Big Data and evaluation.

Keywords: Big Data, Building performance, Facilities management, Usability, Evaluation

1 INTRODUCTION

This paper studies how Big Data can be used in evaluation of buildings, seen from a Facilities Management (FM) perspective. FM is an interdisciplinary approach, integrating principles of business administration, architecture, and the behavioural and engineering sciences (Cotts et al. 2010). Usability evaluations are based on different user's experiences and assessments on how well buildings perform and are related to fulfilment of user needs (Harun et al. 2011). Such usability evaluations are typically based on architecture and the behavioural science. Another approach to building evaluation is Post occupancy evaluation (POE). Since the 1980s the methodology has been developed with focus on POE and building performance evaluation (BPE), as shown by Preiser et al. (1988). As pointed out by Alexander (2010), the emphasis of POE is mainly on the building, while usability appraisal seeks to evaluate the user experience.

Access to good relevant data can be a challenge when evaluating large public building investments (Volden and Samset 2012). This may seem like a paradox, when the volume of data generally increases. However, experience show that data related to the building construction and physical performance of the finished building has been relatively easier to obtain, compared to data that illustrate the user experience of the building. This has been the starting point for looking at the potential of using Big Data in the evaluation of buildings. We have found few publications that explicitly reviewing the use of Big Data for evaluation. In spite of this, there are examples of Big Data that could have relevance to the evaluation of buildings. Some of the examples we have found have a potential to address the user experience of a building. We therefore see a potential for Big Data to be considered as information about the building and its users like required by usability researchers: *"A building's usability is never dependent just on the building itself. It should be seen in the light of the relationship between building and user"* (Lindahl et al., 2013, p. 114). Alexander (2010) has studied the successful interaction between the building, its users and the IT infrastructure with the focus on learning environments. He states that: *"Effective learning environments successfully combine appropriate social and digital environments with the physical environment."* (Alexander, 2010, p.15)

Big Data is a relatively new term that gained acceptance in 2009 (Manyika et al. 2011). A common definition of Big Data is datasets that are so large that they are not suitable to collect, store, process or analyse using traditional database tools (Nature, 2008; Manyika with several 2011). Big Data has some characteristics that make it different compared to structured data in a database. The term "the three Vs" referring to volume, velocity, variety are widely used (Russom 2011). Another characteristic is the availability of real time data. The most important characteristic inherent in the term is that we are talking about data at a large volume. Manyika et al. (2011) state that the global data volumes grow by 40% annually. Data volumes are so large that they are measured in exabytes (one trillion bytes).

There has been a rapid development in the area of Big Data in recent years. The following important developments are worth noting:

- Large quantities of data become available, including data from the internet and data based on sensor and tracking technology
- Increased pressure for making data available
- Access to storage and analysis capabilities at low cost.
- Access to IT platforms to put data into context, such as digital maps for presentation of position data, or building information models (BIM)

Big Data requires new approaches to data analysis for several reasons. Two of the main factors are the size of the data and the unstructured format of the data. Both these factors means that many of the existing data analysis tools struggle to realise the potential of Big Data. Data from multiple sources are aggregated and analysed in new contexts. The potential lies in the linking of data and the ability to see patterns and trends, providing opportunities to extract new knowledge. It is not just access to dynamic data has increased, but also static data digital maps and building information models has become common and readily available. This means that it is now easier to present data in a relevant context.

Hildberg (2013) proposes a classification of different types of data and data sources based on tracking words, locations, nature, behaviour, economic activity, and finally tracking other data. Related to the evaluation of buildings we suggest a division into the following categories according to how data is collected or generated:

- Internet traffic, including activity on social media and data from search engines
- Movement-related data, including GPS, RFID
- Physical environment, typically from different types of sensors
- Commercial activity, the use of payment services and consumption patterns

In addition, there are growing numbers of organisational internal data from FM systems, which is of interest even though the volume does not yet qualify as Big Data.

2 STATE OF THE ART

According to OECD (2000) an evaluation is defined as a “*Systematic and objective assessment of an ongoing or completed project, program or policy, its design, implementation and results*”. Buildings can be evaluated by multiple dimensions, including (Vitruvius, 1960) classic requirements that buildings must fulfil; *firmitas* (strength), *Utilitas* (appropriateness) and *Venustas* (beauty).

Traditionally, most owners and occupants, rarely perform evaluations of how well their buildings perform related to usability aspects. Based on an extensive literature study, Haron et al. (2012) show that usability is a wide concept. As a consequence, several authors (including Jensø et al. (2004), Blakstad et al. (2008) and Blakstad et al. (2010)) argue that evaluations should be based on different methods and aspects, depending on objective, purpose, focus, competence and resources. A systematic evaluation of buildings in use should be an effective way not only to collect information, but also to produce knowledge in relation to the planning of new buildings and for the development of existing buildings.

The term usability has been adapted to buildings through the work in the CIB W111 Usability of workplaces (Alexander, 2004). Usability can be defined as “*the extent to which a system can be used by specified users to achieve specified goals with effectiveness, efficiency and*

satisfaction in a specified context of use” (ISO, 1998). Buildings can be regarded as products to achieve strategic goals such as productivity, innovation and attractivity to mention some relevant goals, as shown by the work of Becker and Steele (1995), Horgen et al. (1999) and Grantham (2000), among others. A usability appraisal will focus on environments, in order to assess their efficiency and effectiveness. It is developed and used various methods for evaluating usability in buildings, for example Usetool (Hansen et al. 2009). Common methods include interviews, questionnaires to users and walk through observation (Harun et al. 2011). Overall, this type of tools provides a good picture of how users perceive one building. Big Data has potential to complement qualitative evaluation methods.

POE is designed to explore in a systematic way how far existing buildings fulfil the objectives of architectural design in reality, i.e., once they are occupied (Preiser et al., 1988). The purpose of POE is to collect information and develop knowledge on the impact that building design and construction decisions have in a long-term perspective. Such knowledge can be utilized for further improvements in the building industry. Steinke et al. (2010) point out that there is no industry-accepted definition of building evaluation, or a standardized method for doing evaluations. An important issue in usability appraisal is to acknowledging the particular setting and context of the study (Alexander, 2010). A usability appraisal will therefore focus more on the user experience, compared to a POE that is more likely to focus on the building.

For evaluation purposes it is not necessarily important to have extremely large amounts of data. Smaller volumes of quantitative data can also be an important contribution to evaluations. Experience from the collection and analysis of real large data sets are, however, relevant for quantitative analysis of small amounts of data as well. For some time, researchers in the field of usability have recognized the need for the development of methods that gives them quantitative data. Blakstad et al. (2008) states that: *“So far in our research, most of the research has been explorative, using qualitative methods, often case studies, as research strategies. For more descriptive and causal studies we will need to develop methods that give us quantitative data and defined indicators that may allow us to benchmark between multiple cases.”* (Blakstad et al. 2008, p 29). This is in line with findings from previous studies showing that evaluations work best when they are based on several methods and data sources (Frechtling, 2002).

3 APPROACH

The results are a summary of findings from literature search and interviews. There are few direct experiences from using Big Data in evaluations. We therefore had to identify applications of Big Data that are relevant to evaluation, and have potential for use in an evaluation context.

In the literature study we have primarily reviewed scientific articles and publications on Big Data, evaluation and usability. The literature on Big Data has covered a wide range of topics including technology solutions, legal issues, applications, innovation, etc. The purpose of the review was to map various aspects of the topic that will be relevant to the use of Big Data in the evaluation of newly build public buildings. Regarding facilities management, literature search was made on the term usability, but also on combinations of evaluation and Big Data with Facilities Management.

The empirical part of the study is based on interviews about the possibilities in using Big Data for evaluation of buildings in a FM perspective. We have interviewed eight IT-specialists, four specialists in FM and three governmental representatives. We conducted interviews with representatives from various organisations with activities related to, or with potential for use of, Big Data. We used a uniform semi-structured interview guide. However, in the interviews with IT-specialists focus came on technical solutions. In the same way, the interviews with FM professionals emphasised data availability and use of analyses and results. With the government officials, we addressed regulations and framework conditions for applications of Big Data. Most interviewees are representing Norwegian organisations, but several of the IT and FM professionals work in an international context. Within a week from the interviews we summarised the results from interviews in an internal memo. These memos were consulted in writing a case study report (in Norwegian). This paper is based on the case study report, with special emphasis on application of Big Data in a FM context. The case study report has also been subject to internal quality assurance from colleagues in the authors' organisations.

4 RESULTS

In the following, we present results from the study. Firstly, we comment on key issues regarding the use of Big Data in evaluation. These issues are availability, applicability, relevance, privacy, ownership, cost and competence. Secondly, we present different types of new data that may be used for evaluation of building usability.

4.1 Availability

The availability of data is controlled by two factors. First, someone must ask for the data. The interviews shows several examples of data that has been available but not used because no one saw the potential. The second factor is that data must be made available for analysis. There is an ongoing trend for disclosure of data. (FAD 2012) A challenge in many evaluation situations is to get data covering long time periods, and especially data describing the situation before a project starts. This could be many years back in time when an ex-post evaluation should be performed. The interviewees highlight that it may be necessary to take steps to ensure that data is stored over long periods of time, so that data is available in an evaluation situation. It requires that one is aware of the type of data that is relevant for an evaluation.

4.2 Applicability

Big Data creates new opportunities to analyse a phenomenon based on different types of data. The interviews illustrate that it is possible to find a set of indicators that are relevant in the evaluation. This should increase validity. In an evaluation context Big Data can be used to:

- Support triangulation and quality assurance of data
- Complement and enhance existing evaluation parameters
- Provide new evaluation parameters
- Provide quantitative data on the conditions previously been based on qualitative assessments
- Illustrate effects that have not been possible to visualize previously

Access to multiple datasets that illustrate the same phenomenon can be used for triangulation. Triangulation can include the use of established types of information, such as interviews and document, but also use of quantitative data, such as sensor data from different sources. We found several examples where sensor data from different systems and different measuring principles can be used to illustrate the same phenomenon. Triangulation can also be done

based on completely different types of data, such as sensor data combined with internet data. Internet data can illustrate how people or the media portrays a new (or old) building.

4.3 Relevance

As pointed out by several of the respondents, Big Data is often collected in an unusual way for a statistician. There is a need for new statistical methods to understand data that is not perfect and not collected for statistical purposes, but still has the potential to be used. Traditional statistical issues such as representative population, significance and selection criteria must be adapted to new types of data. Another concern of the interviewees associated with the use of Big Data in evaluation is that the comparability over time can be difficult. These challenges can be reduced if the data is stored with the highest possible resolution and it stated clearly how the data are collected and processed. The relevance of the data and analyses may also be challenged by the use of aggregated data. If the variation within each group in the aggregates becomes too large, the relevance of the analysis can be questioned.

4.4 Privacy policy

Both from an ethical and legal point of view, it is important to protect personal information and respect people's privacy. This has been a concern in all interviews, although evaluators are typically not interested in studying individual users of a building. Rather, they look for user patterns. Privacy do not need to be an obstacle to the use of Big Data, although it seems to be the issue that people in general are most concerned about. All data that does not include personal information is basically unproblematic, both as individual data sources and the combination of several sources. Combination of different data sources, where there are persons who are the link between the various data is more problematic. Data from different sources with personal data can be combined without revealing personal information, but this can be challenging. Anonymity in datasets is typically achieved by aggregation, where each group includes so many persons that individuals cannot be identified. Another restriction is that in Norway, data should only be used for the purpose it was intended (defined prior to data collection). Our impression from the interviews is that when data is anonymised (for example aggregated) these restrictions do no longer apply.

The use of aggregated data is basically not a problem in research when one wants to uncover trends, patterns, etc. The same applies to an evaluation context. Privacy issues seem manageable, but require access to technical and legal expertise, which may result in additional costs. However, the interviews indicate that it may require that analyses must be done on less detailed data than would have been technically possible.

4.5 Ownership

The legal basis for ownership of Big Data appears to be somewhat unclear to the interviewees. Two principles that several of our interviewees mention are that (1) anyone who collected the data owns them and (2) aggregated data are owned by the person or organisation that did the aggregation. Another important topic today, and especially in the future, will be control of the use of data. This includes issues such as "Who has seen and used a data set, and for what purposes?" The interviewees expect that future data management will not only relate to data collection, storage and analysis, but also to have reliable systems to manage the data use.

4.6 Cost

The interviewees highlight that cost for use of Big Data has been reduced as both storage and analysis capabilities have become cheaper and more accessible through the use of cloud-

based solutions. Collection of data has become cheaper than before. Sensors are readily available, inexpensive, standardised and simpler in installation and operation. If the use of Big Data replaces established data sources, the overall costs are likely to increase, at least initially. The benefits of getting these data can still be large enough to justify the cost. In the event that Big Data can replace more time-consuming and costly data collection for evaluation, it represents an efficiency increase. One can thus do more evaluation for the same amount of money, or reduce the cost of evaluation.

We also note that there is an expectation that data will have a commercial value. But at the same time, the volume of open data is increasing. Competence for analysis and processing of data is also required, and a cost component itself.

4.7 Competence

Several of the interviewees, as well as Manyika et al. (2011), highlighted that available competence can be a limiting factor for the use of Big Data. This appears to apply to a FM contact as well. Skills are needed for identification of relevant data sources, for data collection, analysis and interpretation.

5 PRACTICAL IMPLICATIONS

5.1 Evaluating newly built public buildings using Big Data

For buildings that welcome the public, for example a museum, the experience of Big Data in the retail industry is relevant. The retail industry uses Big Data to analyse customer behaviour both at the aggregate and individual level. At the aggregate level, Big Data can help to identify which products are selling best in different locations and in different customer groups, both inside the store and between stores and regions. To do this, one summarises information about which the customers are, at what time they visit the stores, how they travel to the store, and about purchasing patterns for different customer groups. On the personal level, offers can be tailored to identify customers based on purchasing behaviour (Davenport 2012). In the evaluation of buildings it is mainly principles of the aggregate type of analysis that seems relevant.

It is necessary to distinguish between the construction and operation of the buildings and the activities carried out in the buildings. Those who build and maintain the building are typically concerned with the financial, technical and operational aspects of the building. Clients and customers who use the building are concerned that aspects of the building are affecting the business (for example, increased productivity and collaboration).

Conditions that are interesting related to building usability include:

- Where people are, where they congregate, meet
- Energy use and environmental factors
- Comfort Systems, open window, shield lights, turn on light, temperature, etc. in the building

There are various methods for evaluating usability in buildings. Common methods include interviews, surveys and questionnaires. Overall, this type of tools provides a good picture of how users perceive one building. Evaluation is still primarily based on how the building is used at the time of evaluation. There is a risk that the users involved in the evaluation are

those that are specifically dedicated and examples are the most or least satisfied users. Big Data opens to add qualitative evaluation methods. Big Data illustrate the use of the building over a long period of time and can cover a wide range of users.

Recently, there have been published several examples of evaluation of buildings in use, using quantitative methods based on Big Data approaches. Yoshimura al (2012) logged movement of Bluetooth devices (in practice smartphones) to describe how visitors move in the Louvre Museum in Paris. They contain movement patterns and length of visits. Rawassizadeh et al. (2011) used a camera to record the cleanness of an area. The cleanness was measured by recording changes in the colour intensity over time. They used the colour intensity on a clean surface as a reference. Khani et al. (2011) used special equipment to monitor eye movements. The purpose was to examine the relationship between eye movements and perceived comfort, especially related to different lighting conditions.

Operation and maintenance can be evaluated using new data. It has been done some quantitative evaluation of construction costs, and later evaluation of energy (ZEB 2013). Possibility to use data from different automation systems in buildings increases when such equipment become more common, the data are stored and new approaches to use these data are applied. In addition there is a development of IT systems for planning and monitoring operational and maintenance tasks. This is interesting data, which is now more readily available. But there is at least initially not data in such large quantities that they go under the definition Big Data, without making it less interesting information.

New types of data relevant to the evaluation of buildings include:

- Internet activity: Examples include how the current buildings are discussed on the Internet, Facebook, Twitter etc, how many Google searches are made on the building?
- Location data: how many are in an area in or near the building, time of day/week, where they come from and where they go. Can be based on GPS, mobile phones, access control systems, video cameras, or else.
- Sensors: Logging temperature in the building, the use of different automation systems (lighting, climate, energy), sensors that count the number of passages (into a room, for example)
- Behaviour: What do people do, such as which websites accessed from wireless networks in the building. Login on computers can be used to log the utilization of office jobs.
- Economic activity: Registrations with credit card - when, how people use money?

Table 1 illustrates how different types of Big Data can be utilised in relation to evaluation of buildings. The summary is based on the different Big Data categories.

In addition, table 1 gives some examples of relevant potential data sources, their availability, applicability and relevance. Finally, we give a preliminary judgement of the privacy issues involved. To be able to discuss the involved cost and needed competence, pilot studies are recommended. There are indications that tracking of locations and use of data from different building control systems has the largest potential for use in usability evaluations in the short term.

Table 1: Illustration of use of Big Data in building evaluation

Category	Effect	Indicator	Data source	Availability	Applicability and relevance	Privacy and property rights
Internet activity	Usability	The experience of the building	Mention of the building on the Internet	No access	Relevance of high-profile buildings like the Opera	Not Personal Data
	Efficiency in operations	Type of Use	Websites that sought from the local network	Could be logged. Administrator for wifi system has access	Displays the type of internet activity to building users	Can not be linked to the device (PC, phone, etc.) used
Movements	Efficiency in business, usability	Where people are, their retention	Login at the local wifi network	Could be logged. Administrator for wifi system has access	Showing equipment using wifi / internet	Must be anonymised and / or aggregated
	Efficiency in business, usability	Movements, retention	Access cards	Not a tradition of handing out	Only applicable for areas with access control	Must be anonymised and / or aggregated
	Efficiency in business, usability	Where people are, movements	Video camera	Requires analysis of video	Showing activity where there is a camera	Depending on type of analysis
Physical Environment	Efficiency in business, usability	Use of the building	Light switches, motion sensors in rooms	Not a tradition of storing or handing out	Depends on the type and location of sensors	No personal data for public premises
	Operating Cost	Energy	Energy Management Systems	Store in part for mapping energy	Important cost	No personal data for public premises
	Efficiency in business, usability	Use of the building	Energy Management Systems	Store partially	The focus on energy consumption, but also illustrates the use	No personal data for public premises
	Usability	Indoor air	Air conditioning, CO measuring		Part of usability	No personal data for public premises
Commercial activity	Efficiency in operations	Number of users, type of use, revenue	Use of payment cards	Not a tradition of handing out	Important information for commercial premises	Privacy
Internal records / data	Operating Cost	Maintenance Activity	Operating and maintenance systems	Related info with the building manager	Shows the level of usage and kindness in technical solutions	Not Personal Data
	Operating Cost	Cost of operation and maintenance	Accounting system	Facilities manager may have this	Displaying cost, life cycle cost	Not Personal Data
	Operating Cost	Scope of modification	Area registry and accounting	Facilities manager may have this	Showing adaptability	Not Personal Data

5.2 Reflections on practical implications

Our study has attempted to look into the various areas that are important for the potential use of Big Data in the evaluation availability, applicability and relevance, privacy and ownership, cost and competence. Privacy concerns, property rights and competence influence availability of data. We find that privacy and property rights are not necessarily an obstacle for the use and analysis of Big Data. The legislation and privacy concern does generate various challenges that influence the availability and use. It seems that the technological development has run in front of the legislation. This applies to both national and to an even larger extent international legislation and guidelines. People with appropriate competence for research, data collection, analysis and visualization are a scarce resource and may limit the potential for use of Big Data both in Norway and internationally. Our impression is that the different types of Big Data probably have a major potential to be used in evaluations. In particular, several different data sets that illustrate the same phenomenon can be used for triangulation and quality assurance of facts evaluations. The utility can be somewhat reduced when data is available in many different formats.

Big Data creates new opportunities to analyse a phenomenon based on different types of data. This increase the opportunities for the evaluator to find indicators that are relevant to the building being evaluated. However, the applicability and relevance is challenged in at least two ways. One is that Big Data means a new way to deal with information and may require new use of statistical methods. Traditional statistical issues must be adapted to new types of data. The second challenge is the need for data covering a relatively long time period, typically a few years. We recommend that data is stored with the highest possible resolution and it is clearly described how the data are collected and processed. In addition, measures are taken to store data it is stored for long time periods.

6 CONCLUSION

Big Data is an area of rapid development. It published a lot on the topic in general, and both practitioners and academics see opportunities. Much has been done in the private sector (including retail, business analysis), while the public sector appears to be somewhat behind. There are some published results related to an FM context, but it appears to be a potential for more FM applications in general. We have studied evaluations on buildings and usability. It seems to be great opportunities for using new (large) data in building evaluation. We have found several examples of creative use of Big Data relevant to usability evaluation, but few have explicitly used data from intelligent buildings to evaluate building usability.

We recommend pilot studies, where one tries to use various forms of Big Data in performing evaluations. A likely role for FM professionals is to contribute to the initiation of pilot projects by identifying appropriate measures, appropriate types of data, help in interpreting the data and putting them into an evaluation context. It is likely that we need assistance related to data acquisition and analytics. This is an area of very rapid development, and apparently with a large potential to move usability evaluation of buildings towards a new dimension.

REFERENCES

- Alchian, A., Harold D. (1972), Production, Information Costs, and Economic Organization. 62. *American Economic Review* 777-95.
- Alexander K. (2008), Usability: philosophy and concepts. In *Usability of Workplaces, Phase 2*. CIB W111 research report.
- Alexander, K. (2010), Usability of Learning Environments, *W111 Research report Usability of Workplaces, phase 3*, available at: <http://cibworld.xs4all.nl/dl/publications/pub330.pdf> (accessed on 4 February 2014), p 5-16
- Becker, F., Steele F. (1995) *Workplace by Design: Mapping the high performance workspace*. San Fransisco, CA: Jossey-Bass
- Belassi, W., Tukel, OI, (1996). A new framework for deter mining critical success / failure factors in projects. *Management Information Systems*, 10 (2), 203-255
- Blakstad, S. H., Hansen, G. K., Knudsen, W. (2008), Methods and tools for evaluation of usability in buildings, Alexander, K. (Ed.), *W111 Research report Usability of Workplaces, phase 2*, available at: <http://ntnu.diva-portal.org/smash/get/diva2:134056/FULLTEXT01> (accessed on 4 February 2014)
- Cesario, S. (2009), Designing Healthcare Environments: Part I. Basic Concepts, Principles, and Issues Related to Evidence-Based Design. *The Journal of Continuing Education in Nursing*. 40 (6), 280-288.

- Chomitz, KM (2010), Big Data for Development: From Information to Knowledge-Societies. *Computing*, Vol. 9, no. 1, pp. 13-19, January-March 2010.
- Cotts, D., Roper, C., Payant, R. (2010) *The Facility Management Handbook*. 3rd ed. Amacon, New York.
- Curtis, V. (2007), Dirt, Disgust and Disease: A Natural History of Hygiene. *Journal of Epidemiology and Community Health*. 61 (8), 660-664.
- Davenport, TH (2012), Enterprise analytics. *Optimize performance, process and decisions through Big Data*. FT Press, Upper Saddle River, NJ
- Datatilsynet (2013), Big data er deg. [http://www.datatilsynet.no/verktoy-skjema/Publikasjoner/Analyser-utredninger/Big Data are-you /](http://www.datatilsynet.no/verktoy-skjema/Publikasjoner/Analyser-utredninger/Big%20Data%20are-you/). Downloaded 30/07/2013
- Economist (2013), Do not even think about it. *The Economist* July 20th 2013, pp 22-23
- EN 15221-1 (2007), Facility Management Part 1: Terms and Definitions.
- Facebook (2013), Facebook developers, Insights. <https://developers.facebook.com/docs/insights/>
- FAD (2102), Public agencies unleash public data. News, 31.05.2012. Ministry of Government Administration, Reform and Church Affairs.
- Frechting, J. (2002), *The 2002 User-Friendly Handbook for Project Evaluation*. National Science Foundation, Directorate for Education and Human Resources, Arlington
- Forskning.no (2013), Democracy version 2.0. 11August 2013. <http://www.forskning.no/artikler/2013/august/363925>
- Girardin, F., Calabrese, F.D., Fiore, C., Ratti, Blat, J. (2008), Digital footprinting: Uncovering tourists with User Generated content, *IEEE Pervasive Computing*, vol. 7, pp. 36-43, Oct. 2008.
- Grantham C (2000). The future of work. *The promise of the new digital work society*. New York, NY:McGraw-Hill, Commerce Net Press
- Harrison, A., Loe, E., Read, J., (1998), *Intelligent Buildings in South East Asia*, E & FN SPON, London,
- Hansen, G.K., Blakstad, S.H, Knudsen, V. (2009), *USEtool, Evaluering av brukskvalitet, METODEHÅNDBOK*. SINTEF / NTNU. <http://www.metamorfose.ntnu.no/Dokumenter/USEtool>
- Haron, S.N., Hamid, Y., Talib, A. (2012) Towards Healthcare Service Quality: An Understanding of the Usability Concept in Healthcare Design. *Procedia - Social and Behavioral Sciences* 42 (2012) pp 63 – 73
- Harun, S.N., Hamid, M.Y. Talib, A., Rahim, Z.A (2011). “Usability Evaluation”: Criteria for Quality Architecture In- Use. *Procedia - Engineering* 20 (2011), pp 135–146
- Hilbert, M. (2013), Big Data for Development: From Information to Knowledge Societies- <http://ssrn.com/abstract=2205145>
- Horgen, T., Joroff , M., Porter, W., Schon, D. (1999). *Excellence by design*. New York, NY:Wiley
- Junghans, A. (2012), Integration of Principles for Energy-efficient Architecture and Sustainable Facilities Management. *28th International PLEA Conference Opportunities, Limits & Needs Towards an environmentally responsible architecture*. LIMA, 7–9 November 2012.
- Lindahl, G., Hansen, G.K., Alexander, K. (2013), “The Usability of Facilities, Experiences and Effects”, Alexander, K., Price, I. *Managing Organizational Ecologies: Space Management and Organisations*, Routledge, pp 105-116.
- Manyika, J. Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C., Byers, A.H. (2011), Big Data: The next frontier for innovation, competition, and productivity. McKinsey Global Institute
- MIT (2013), Sense Able city lab <http://senseable.mit.edu/> downloaded 07/30/2013

- Morgenbladet (2013), Will revolusjonere samfunnsvitenskapene. Morgenbladet 9 August 2013. http://morgenbladet.no/samfunn/2013/vil_revolusjonere_samfunnsvitenskapene
- Nature Editorial. (2008), Community cleverness required. *Nature*, 455 (7209), 1 doi: 10.1038/455001a
- Powell, J.A. (1990), Intelligent design teams design intelligent building, *Habitat International* 14 (2/3) (1990) 83– 94.
- Preiser, W., Vischer, J. (2005), The evolution of building performance evaluation: an introduction. In: Preiser, W. Vischer, J. (eds.) *Assessing Building Performance*. Elsevier Butterworth-Heinemann, Oxford.
- Preiser, W., Rabinowitz, H., White, E. (1988), *Post-Occupancy Evaluation*. Van Nostrand Reinhold, New York.
- Rawassizadeh, R., Khosravipour, S., Tjoa, A.M. (2011), A Persuasive Approach for Indoor Environment tidiness. In *the 6th International Conference on Persuasive Technology*.
- Schweitzer, M., Gilpin, L. & Frampton, S. (2004), Healing Spaces: Elements of Environmental Design that make an Impact on Health. *The Journal of Alternative and Complementary Medicine*. 10 (1), 71-83.
- Vitruvius, M. (1960), *The Ten Books on Architecture*. New York: Dover.
- Volden, G.H., Samset, K. (2013), *Etterevaluering av statlige investeringsprosjekter. Konklusjoner, erfaringer og råd basert på pilotevaluering av fire prosjekter* . Concept Report No. 30 Norwegian University of Science and Technology University. http://www.concept.ntnu.no/Publikasjoner/Rapportserie/Nr.%2030_webutgave30_norsk.pdf
- Yoshimura, Y., Girardin, F., Carrascal, JP, Ratti, C., Blat, J. (2012), New tools for studying visitor behaviors in museums: a case study at the Louvre. MIT: Sense Able city lab <http://senseable.mit.edu/> downloaded 07/30/2013
- ZEB (2013), Zero Emission Buildings. <http://www.zeb.no/index.php> Downloaded 01/08/2013

10.2

TOOLS FOR STAKEHOLDER INVOLVEMENT IN FACILITY MANAGEMENT SERVICE DESIGN

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ABSTRACT

Purpose: The purpose of this paper is to provide an overview of the tools that Facility Management (FM) companies use to involve different stakeholders, and more precisely the ones on the demand side, in the FM service design process. Stakeholder involvement may contribute to FM service innovations that are more in line with the stakeholder needs and expectations, and may thus result in increased customer satisfaction, better services and, at the very end, an increased competitive advantage for the organization.

Background: The background of this study lies in user involvement in service design in combination with empirical evidence and research from the FM field. The differentiation between clients, customers and end-users (Coenen et al. 2013) is taken as the ground to explore the peculiarities of stakeholder management within FM service design, and deepen the discussion on user involvement, which can be found in service design literature.

Methodology: To address the purpose of the study, this article uses a qualitative research design and combines an extensive literature review with semi-structured interviews and archival data from both primary and secondary sources.

Results: This study provides an overview of the specific tools that are used to involve different stakeholders on the demand side in FM service design and innovation process. These tools have been categorized as: (1) direct methods that allow stakeholders (clients, customers and end-users) to actively participate in the FM service design and innovation; and (2) indirect methods that enable to passively involve stakeholders through ethnographic methods.

Practical implications: Practitioners could use the results of this study in the FM service design process to (1) identify which demand stakeholders they want to involve, i.e. client, customer, or end-user; (2) identify which type of involvement, i.e. as co-creator, resource or user, is called for in the specific design process; and (3) choose the design tools to support the FM service design process in each specific instance.

Originality/value: By taking the starting point in the literature on service design, user roles in service design and tools for service design, this paper contributes to FM literature by (1) first identifying the tools used by FM managers to involve users in FM service design processes and (2) by categorizing such tools in relation to the role that FM users have in the design process as well as FM service provision processes.

Research limitations: The major limitation of the study consists of the relatively small amount of interviews conducted, which is the basis for finding the tools in FM service design processes.

Keywords: Services, Facility Management, Design, User involvement, User roles

1 INTRODUCTION

Service design is increasingly becoming a popular subject both in academia and in the business world, especially among consulting companies. Recent literature on new service development and service design has found that organizations, which are most successful in providing new services, engage in a strategic and planned approach to service design. As Bitner, Ostrom and Morgan (2008) state, in fact, successful service designers “prepare and move systematically (and often iteratively) through a set of planned stages, from the establishment of clear objectives, to idea generation, concept development, service design, prototyping, service launch, and customer feedback” (Bitner et al. 2008: 4). Existing literature outlines a number of tools for service design, which draw on different fields such as service design (e.g. Morelli 2006), innovation theory and new service development (e.g. Scupola & Nicolajsen 2013) but also marketing and management disciplines (Shostack 1982; Shostack 1984). Furthermore, recent literature has stressed the importance of involving users and customers in the service innovation process and design (e.g. Alam & Perry 2002; Morelli 2009).

Among other service contexts, research on facility management (FM) service design is increasingly developing. For example, Felten, Coenen and Pfenninger (2012) show how FM service blueprinting can add value in the FM service design process, while Lee (2011) employs a service design approach to healthcare servicescapes and suggests a conceptual framework to help designers interested in patient-centred healthcare facilities.

Given this background, the purpose of this article is to present and discuss some of the tools that FM organizations are using to design and develop FM services that are stakeholder centric or that, at least, explicitly take into considerations the different stakeholder needs. To do so, this paper draws on the concepts of user involvement in new service development as conceptualized by Alam and Perry (2002) and literature on design tools (Bitner et al. 2008; Magnusson et al. 2003; Morelli 2006; Morelli 2009; Scupola & Nicolajsen 2013; Shostack 1987). Involving users in FM service design and development is important since it may lead to FM service innovations, which are more in line with user needs and expectations and which may therefore result in increased customer satisfaction, services with lower failure rates and, at the very end, increased competitive advantage of the company.

The article is structured as follows. The introduction presents the background and the purpose of the paper. The second section presents the theoretical background. The third section discusses the research method, while the fourth section presents an overview of the tools used in FM services design. Finally, the last section presents some concluding remarks.

2. STATE OF THE ART

2.1 Understanding FM services

According to Bitner et al. (2008) one of the most distinctive characteristics of services is their process nature. Unlike physical goods, services are dynamic and unfolding over a period of

time through a sequence or constellation of events and steps. In addition, the service process can be viewed as a chain or constellation of activities that allow the service to function effectively (Shostack 1982; Shostack 1984). Existing literature argues that the best way to understand services is to understand the service process, which applies also for FM services. Felten et al. (2012: 238), for instance, state that, according to the European Standard on FM processes, process activities in FM services (1) are actions taken by specific persons in a planned order to reach a target outcome; (2) have to take place in a logical sequence; (3) are carried out with identified responsibilities; and (4) have to be planned before the process is to be carried out. The planning of the execution, which is intended as preparation before the implementation, is considered to be the first and most important activity. In addition, a mixture of providers, which include internal FM units and external parties to whom services are outsourced, is responsible for the provision of such process activities in FM services.

Therefore, involving customers in FM service process design is complicated not only by the combination of internal and external providers, but also, and especially, by the multidimensionality of customers themselves. The European Standard on FM Terms and definitions, in fact, differentiates between (1) “client”, which is defined as the organization that specifies FM needs, and procures FM services by means of a FM agreement; (2) “customer”, which is defined as an organizational unit that specifies and orders the facility services within the conditions of the FM agreement; (3) “end users”, which are defined as the individuals who receive FM services in a permanent or temporary way (Coenen et al. 2013; Felten et al. 2012). In this paper we refer to stakeholders – and not to users – in the attempt to stress the complexity of the FM value chain. Nevertheless we acknowledge the importance of approaching FM with a demand driven, service-oriented and user focused perspective (Coenen et al. 2013), which is why our study emphasises the involvement of the stakeholders on the demand side, i.e. client, customers and end-users.

2.2 Service Design and User Involvement

Much of today’s design science and design thinking is inspired by Herbert Simon’s (1965) phases of intelligence, design and choice. Morelli (2009) argues that most authors in the service design literature refer to three phases, which are very similar to those outlined by Simon (1965): (1) a first phase of analysis and investigation, (2) a second phase of concept development and (3) a third phase of choice/selection, where specific solutions are identified. Since one main characteristic of services is that the customer is essential in the service provision process, the user/customer should be included in the service design process. Indeed, FM service design should involve the FM service providers as well as the customers/users. However, even though a significant portion of the literature has addressed customer involvement in the final act of service providing, by focusing, for example, on the moment of truth, customer experience, or service co-creation, user involvement in service design has only been limitedly addressed (Magnusson et al. 2003), especially in the FM context.

To illustrate the tools that can be used in FM service design, this paper draws on the differentiation among client, customer, and end user in FM services described above. In addition, this study draws on the three roles that customers can have in new product development as described by Nambisan (2002) and lately applied in the context of new service development by, for example, Scupola and Nicolajsen (2010). These roles are: “customer as a resource”, “customer as co-creator” and “customer as user”.

According to Nambisan (2002), the contribution of customers as a *resource* varies with the maturity of the technology and the alignment of the product line with the customer base. In the case of continuous innovations, customers are generally passive and firms have to find out about the customers opinion through market surveys or focus groups. Previous literature (e.g. Matthing, Sandén, & Edvardsson 2004; von Hippel 1986) also argue that there are a number of challenges related to using customers as a resource in idea generation, which include selection of customers, creation of incentives to foster customer participation and capturing of customer knowledge. As *co-creators*, customers can participate in a number of activities varying from design activities to development activities. Potential incentives that motivate customers to involve themselves as co-creators or co-producers include enhanced self-esteem, greater opportunities to make choices and greater customization. According to Nambisan (2002) customer-firms interactions tend to be much more intense and frequent during co-creation, and mechanisms to support such interactions are costly and technology intensive. Finally, in their role as *users*, customers can provide value in two ways during the service process: (1) service testing and (2) support. For example, the involvement of users in product testing can be used to identify problems early on in the development phase, thus minimizing the costs of redesign and re-development.

2.3 Tools for service design

Previous literature has identified a number of tools used by designers in the different phases of the service design process and in different contexts. For example, engineering designers have traditionally used marketing tools, e.g. questionnaires, interviews and focus groups, in the earliest phases of the design processes (Morelli 2006). However, tools and methods deriving from the social science and anthropology are becoming more and more popular among service design scholars (Morelli 2009). These tools include (1) mapping and profiling tools to map the actors of the service system or their profiles; (2) ethnographic methods, e.g. use and interpretation of videos to document reality, and cultural probes, as a way of encouraging users to record relevant information in photographs, personal diaries and other forms of inspirations (postcards, questions and pictures); and (3) service blueprinting, a process analysis methodology. The latter was proposed by Shostack (1982) with the aim of codifying knowledge, skills and particular events that happen in a service provision and consumption, to generate a support for its reproducibility. Morelli (2009) highlights how service blueprinting assumes customers to play a rather passive role, which can be turned into active participation through design orienting scenarios, which are focused visions of the future that can orient the action of a small group of stakeholders, local actors and possible customers. The scenarios are usually developed through a series of brainstorming sessions with all the actors and should take into account the complex interaction between different factors (Morelli 2009). To describe the most critical instances and occurrences in a scenario, service design scholars have used use case methodology (Morelli 2002; Morelli 2006). According to Morelli (2009: 580) “scenarios and use cases are good methods to involve different actors in the design process. Actors (final users and local service providers) can participate to their development by using plain language explanations or requirements”.

For the purposes of this paper, the tools that can be used to involve the customer/user in the FM service design process are distinguished into two main categories: face-to-face and virtual (Information and Communication Technology (ICT)-based) tools (e.g. Prandelli et al. 2008; Scupola & Nicolajsen 2013). An example where ICT-based tools were used to directly involve customers in the design process is the use of e-forums by Lego, where customers have been recruited to engage in software code development for LEGO mind storm. In addi-

tion, the distinction is made here between tools that require direct and pro-active involvement from the participants, such as workshops; and tools where the participants have just a passive role, as in most ethnographic methods. A taxonomy of service design tools is illustrated in Table 1 below.

Table 1: A taxonomy of service design tools (Adapted from Scupola and Nicolajsen, 2013)

Categories of Service Design Methods	Face-to-Face Methods	ICT-based Methods
Examples of “direct methods”	Workshops (e.g. future workshops) Interviews Focus groups Ethnographic methods (cultural probes) Qualitative service blueprinting (design orienting scenarios and use case methodology)	Idea competitions Blogs Facebook e-forums
Examples of “indirect methods”	Mapping and profiling tools Ethnographic methods (documentation of reality) Paper based surveys Complaint box	Online discussion groups Virtual communities Online surveys

3 APPROACH

To find the tools used in FM service design, a qualitative research method has been chosen because qualitative data “are the source of well-grounded, rich description and explanations of processes [...] and help researchers go beyond initial pre-conceptions and frameworks” (Miles & Huberman 1984: 15). By following Miles and Huberman (1984)’s guidelines for conducting qualitative research, this research started with a literature review of studies investigating service design and service design tools and was followed by an empirical investigation in the FM field.

Data for the study were gathered from archival sources, interviews with companies as well as attendance in practitioner conferences and workshops on the topic of FM service design and innovation. In all, 19 explorative, semi-structured interviews among FM service practitioners, i.e. facility managers working in internal FM units and outsourced FM providers, were carried out in 15 Danish companies. The interviews aimed at collecting data on FM service development with focus on user involvement in FM service design, and the face-to-face and ICT-based tools used to support such design process.

The interviewees were selected with a combination of convenience (at the beginning) and snowball (later on) sampling criteria (Eisenhardt 1989). All interviews were tape-recorded and transcribed, and notes were taken both during and after the interviews. To increase reliability, an interview protocol was used and a database was developed (Yin 2009). The respondents, all senior managers or directors, were somehow involved with FM design and innovation processes within their organizations.

To complement the interview data and ensure triangulation (Eisenhardt 1989; Yin 2009), archival data, i.e. reports, power point presentations, emails, newsletters, corporate brochures,

were collected both from the interviewees and from secondary sources, such as corporate websites and conferences, and were analysed along with the interview data through subsequent steps of open and axial coding with the support of the qualitative data analysis software Atlas.ti. The data were analysed from the perspective of the outsourced provider and the internal FM unit, which, within the FM context, is not only the customer but also the internal provider of the client organization. When investigating user involvement in FM service innovation processes, it is interesting to look at how the internal FM unit (a) is involved as customer in relation to the outsourced FM provider; (b) involves top management and employees when developing new services together with the outsourced provider. The setting in which we investigate user involvement is thus a complex setting constituted by the relationship between the client organization and the outsourced FM service provider.

4 RESULTS

4.1 FM service design and user involvement

In FM services, top management, internal FM managers and end-users, as diverse users, may play different roles when involved in FM service design processes (Coenen et al. 2013; Felten et al. 2012). The empirical evidence collected here indicates that in FM service design processes, not only the involvement of users is variable depending on the offered services (Alam & Perry 2002), but also on the specific role that FM users play with regards to the service being designed.

FM strategic decisions, for instance, cannot be made solely by the outsourced FM providers, but require the involvement of the FM client to ensure the proper matching between the FM strategy of the client organization and the actual development and implementation of the new FM service. The FM client is usually involved indirectly with the outsourced FM providers through the internal FM unit, which acts as an intermediary to ensure the proper matching between the client and the external provider. The internal FM unit is in charge of integrating all strategic consideration in the FM design process that is undertaken by the outsourced FM provider.

When the FM development process under consideration does not strategically and/or financially concern the client organization as a whole, e.g. in the case of single FM service innovations, the main actor becomes the internal FM unit, which either influences the suppliers indirectly by setting the guidelines (involvement as resource) or works on the strategic planning and on its implementation together with the outsourced providers (involvement as co-creator).

The outsourced FM service providers usually manage the FM service design process together with the internal FM unit, and are usually held responsible for operational decision-making, especially when the service in question does not directly affect the strategic level of the client organization. In a logistic service provider, for instance, the head of Global Facility Management stated that suppliers should be in charge of the operational tasks of the innovation process, especially the idea generation, while the internal FM unit would rather be involved in the idea selection to make sure that all needs and expectations of internal stakeholders were taken into consideration:

“We write in your Site Service Agreements that we want to see improvement suggestions one, two or three times per quarter, per month, whatever it is, for these regular meetings. And

then it's of course up to me to say "no, I don't want this", but I want to have the choice to say no." (Head of Global FM, Logistic Service Provider)

FM end-users often seem to be indirectly involved in various phases of NSD processes through the intermediate action of the internal FM unit. FM end-users, in fact, tend to not be called to participate actively in strategic decisions, as their heterogeneous needs are believed to not correspond to those of the organization as a whole, and to be too operational. Their involvement would be too complex and resource consuming. On the other hand, both the internal FM unit and the outsourced providers support the involvement of end-users in operational activities through surveys and seasonal collection of feedback, as it allows a better understanding of end-users' needs and expectations.

4.2 Tools for user involvement in the FM service innovation process

Among the support tools for FM service design, our study shows that workshops are the preferred tool in most FM user roles. This study shows that traditional marketing tools such as questionnaires, focus groups and interviews are used mostly for involving FM end-users as users in the initial phases of the service development process, while workshops support a more direct and active involvement of clients in the first phase of analysis and investigation of the FM design process (Simon 1965). The respondents have depicted workshops as useful support tools in heterogeneous FM service design situations, as they can be adapted in the structure and functioning to specific FM design contexts and needs. For example, workshops with the participation of outsourced providers and internal FM units are used to involve the latter as users (e.g. for testing marketing approaches), as co-creator (e.g. for personnel training), and as resource (e.g. for selecting the best ideas for implementation).

The study shows that top management, however, needs to be involved through less "demanding" types of design tools such as regularly organized and ad hoc meetings, facilitated for example by scenario analysis and transparency models (Morelli 2009). This is due to the need to demonstrate the professionalism and value of FM services for the client organization, along with the non-strategic importance that top management of the client organization tends to attribute to FM services.

ICT-based tools are mostly used to support information management and sharing. In some cases as for example in scenario analysis and transparency matrices, ICT-based tools are used to facilitate communication between different users as for example between internal FM unit and top management of the FM client organization. On the other hand, the importance of partnership-like relationships between the FM client and the FM outsourced providers, based on trust, increases the relevance of face-to-face meetings, especially to support involvement as co-creators of, not only the internal FM unit, but also of top management and end-users.

End-user involvement appears to be supported mainly through ICT-based user-surveys and interviews, which allow collection of end-user perspectives without direct involvement (requiring more intermediating effort by the internal FM unit). Nonetheless, end-users are sometimes involved as co-creators through idea competitions and workshops, which not only support the new FM service development, but also increase awareness of FM services within the organization. The aim of such initiatives combines (a) collecting feedback on existing FM services to better match needs and expectations in the ones to be (re)designed; (b) asking for potential ideas for improvements and design of new FM services; (c) build or increase awareness on the activities of the FM unit.

In addition, ideas and feedback are continuously collected per email and/or Customer Relationship Management (CRM) tools. End-users have the possibility to submit their feedback and proactive ideas to the internal FM unit, which operates as filter, and pre-selects the ideas to submit to the FM outsourced provider for screening and, potentially, development. For instance, while designing and developing a new, integrated set of services for a specific FM client, one of the FM providers interviewed the end-users to delineate their needs and expectations and used that input to generate new ideas:

“The investigation was about having workshops with the client’s and our employees to understand and we actually said: we are on your side, what gets in your way? How is it to come to the parking lot? How is the reception? What do you spend time on? What doesn’t work? What’s the hassle?” (Commercial Director and CFO, FM Service Provider).

Tools such as shared training and team-building activities are also used as ethnographic methods to indirectly and directly involve end-users as resource and co-creators. In fact, by creating cross-functional teams and organising team building exercises with employees from both the FM client and FM provider organization, FM service designers have the opportunity to get closer to the actual needs and expectations of both end-users and customers. The study shows that, besides allowing for mapping and profiling of end-users and customers (involvement as resource), participation in such activities encourages end-users and customers either to share knowledge for and/or actively participate in the FM service design and development (involvement as co-creator). For instance, the FM team of a financial service provider was invited to a cooking class together with the FM service provider team with the aim of increasing socialization among the two teams and elicit knowledge sharing both to support the development of new FM services and the improvement of the existing ones:

“...They actually came with a very famous chef in Sweden and we cooked with him at night. So we were five teams and we were split up so we were one or two from the provider and one or two from us and we had to make a main course, and a starter, and whatever. Just trying to break down these barriers, so people start to share knowledge...” (Head of Contract Management and IFM development, Financial Service Provider)

A summary of the support tools that this study found to be used to facilitate user involvement in FM service design is provided in Table 2. These tools are classified in relation to the roles of the stakeholders and their involvement in FM service design processes. Furthermore, Table 2 distinguishes between direct and indirect methods, as depicted in Table 2, whereas the tools supported by ICT are denoted with asterisks (*).

5 PRACTICAL IMPLICATIONS

This study is of practical importance to FM service firms interested in developing their FM services. In fact, Table 2 could be used as an inspiration for FM service designers and developers concerning which kind of methods to use to involve different stakeholders in the FM service design process. The results of this study show the importance of planning for stakeholder involvement in the FM service development and design process as well as the importance of choosing the right support tools for the type of stakeholder involved in the specific design phase and process.

Table 2: A summary of tools for stakeholder involvement in FM service design

		Co-creator	Resource	User
Client/organisation	Direct methods	Regular and ad hoc meetings Workshops	Workshops Qualitative service blueprinting (design orienting scenarios and use case methodology)*	Ad-hoc meetings
	Indirect methods	N.A.	N.A.	N.A.
Customer/internal FM unit	Direct methods	Face-to-face meetings Workshops Ethnographic methods (Team-building activities) Qualitative service blueprinting (design orienting scenarios)*	Workshops Ethnographic methods (Shared training; Team-building activities)	Workshops
	Indirect methods	Mapping and profiling tools*	Mapping and profiling tools*	N.A.
End-user/employees	Direct methods	Ethnographic methods (User workgroups)	Face-to-face interviews Workshops Ethnographic methods (Idea competitions*; Team building activities; Shared training)	Workshops Ethnographic methods (User workgroups)
	Indirect methods	N.A.	User surveys* Mapping and profiling tools*	User surveys*

More specifically, practitioners could use the results in Table 2 in FM design processes to first identify which stakeholder they want to involve, i.e. client, customer, or end-user. Secondly, Table 2 can be used to identify which type of involvement, i.e. as co-creator, resource or user, the stakeholders should take in the specific design process. Finally, practitioners can get an idea of the design tools used in FM service design processes and eventually choose among the design tools described in Table 2 to support the process in each specific FM service design instance.

For example, a new FM service development project that requires significant investment and commitment from the client as in the case of shifting from open offices with assigned seats to activity-based office spaces, could, first of all, involve top management as “resource” in order

to make the decision of whether to implement the idea or not. In addition, FM providers could support the involvement of the client by organising workshops to discuss the new idea of the office space and/or by presenting scenario analyses and transparency matrices to facilitate involvement in the decision-making. Once the decision is made, it might be necessary to involve end-users as co-creators in the design of the activity-based offices, to ensure that all activities that need to be carried out by the employees, have a dedicated space and are serviced appropriately (with cleaning, technical maintenance and so on). In this case, user workgroups could be created to develop a series of proposals, which could then be assessed by the FM providers and integrated, when possible, in the new office space design.

6 CONCLUSION

The aim of this paper was to present and discuss some of the tools that FM organisations use to design and develop new and improved FM services with the involvement of clients, customers, and end-users. The results of the analysis indicate that the involvement of the different users – here called stakeholders – is variable depending not only on the offered FM services (Alam & Perry 2002), but also on the specific role that users may play with regards to the FM service to be (re)designed and developed. Such heterogeneity of roles across the service design and development process implies that different tools are required to ensure the success of stakeholder involvement. The major contribution of the study is providing an overview of the specific tools that are used to involve stakeholders in FM service design and development processes. These tools have been categorized as follows: (1) direct methods, which allow stakeholders to actively participate in FM service design (regular and *ad hoc* meetings; workshops; interviews; cultural probes; quality service blueprinting; idea competitions; user workgroups; shared training and team building activities); and (2) indirect methods, which enable to passively involve stakeholders through observation (mapping and profiling tools; user surveys).

The results of this study are important to FM scholars and practitioners alike. First of all, this is the first study to the best of our knowledge, which investigates the tools for user involvement in the context of FM service design. This can be of interest to service design and innovation scholars in general, and FM scholars in particular. This study is also relevant to FM practitioners, because they can get inspiration about the support tools that can be used by FM managers for stimulating active participation and managing passive contribution of stakeholders in FM service design processes.

Finally, this study is not free of limitations. Firstly, the results are based on a relatively small number of interviews, which probably makes the list of tools not exhaustive. Secondly, the analysis has been based on theoretical models developed in business-to-consumer contexts, which were applied in a complex business-to-business FM context, even though it may be argued that our analysis was conducted at individual level of involvement. To overcome these limitations and increase the generalizability of the results, similar studies could be conducted within FM services as well as other support services to further investigate methods and tools to support the successful involvement of stakeholders in service design.

REFERENCES

Alam, I. & Perry, C., 2002. A customer-oriented new service development process. *Journal of Services Marketing*, 16(6), pp.515–534.

- Bitner, M.J., Ostrom, A.L. & Morgan, F.N., 2008. Service Blueprinting: A Practical Technique for Service Innovation. *California Management Review*, 50(3), pp.66–94.
- Coenen, C., Alexander, K. & Kok, H., 2013. Facility management value dimensions from a demand perspective. *Journal of Facilities Management*, 11(4), pp.339–353.
- Eisenhardt, K., 1989. Building theories from case study research. *Academy of management review*, 14(4), pp.532–550.
- Felten, D. Von, Coenen, C. & Pfenninger, M., 2012. Analysing Added Value by Applying FM Blueprinting. In P. A. Jensen, T. Van Der Voordt, & C. Coenen, eds. *The Added Value of Facilities Management: Concepts, Findings and Perspectives*. Lyngby: Polyteknisk Forlag, pp. 235–247.
- Gallouj, F. & Weinstein, O., 1997. Innovation in services. *Research policy*, 26(4-5), pp.537–556.
- Von Hippel, E., 1986. Lead Users: A Source of Novel Product Concepts. *Management Science*, 32(7), pp.791–805.
- Lee, S., 2011. Evaluating Serviceability of Healthcare Servicescapes: Service Design Perspective. *INTERNATIONAL JOURNAL OF DESIGN*, 5(2), pp.61–71.
- Magnusson, P.R., Matthing, J. & Kristensson, P., 2003. Managing User Involvement in Service Innovation: Experiments with Innovating End Users. *Journal of Service Research*, 6(2), pp.111–124.
- Matthing, J., Sandén, B. & Edvardsson, B., 2004. New service development: learning from and with customers. *International Journal of Service Industry Management*, 15(5), pp.479–498.
- Miles, M.B. & Huberman, A.M., 1984. Qualitative data analysis: a sourcebook of new methods.
- Morelli, N., 2002. Designing Product/Service Systems: A Methodological Exploration. *Design Issues*, 18(3), pp.3–17.
- Morelli, N., 2006. Developing new product service systems (PSS): methodologies and operational tools. *Journal of Cleaner Production*, 14(17), pp.1495–1501..
- Morelli, N., 2009. Service as value co-production: reframing the service design process. *Journal of Manufacturing Technology Management*, 20(5), pp.568–590.
- Nambisan, S., 2002. Designing virtual customer environments for new product development: toward a theory. *Academy of Management Review*, 27(3), pp.392–413.
- Prandelli, E., Swahney, M. & Verona, G., 2008. *Collaborating with Customers to Innovate: Conceiving and Marketing Products in the Networking Age*, UK: Edward Elgar Publishing.
- Scupola, A. & Nicolajsen, H.W., 2010. Service innovation in academic libraries: is there a place for the customers? *Library Management*, 31(4/5), pp.304–318.
- Scupola, A. & Nicolajsen, H.W., 2013. Using Social Media for Service Innovations: Challenges and Pitfalls. *International Journal of E-Business Research*, 9(3), pp.27–37.
- Shostack, G.L., 1984. Designing services that deliver. *Harvard business review*.
- Shostack, G.L., 1982. How to Design a Service. *European Journal of Marketing*, 16(1), pp.49–63.
- Shostack, G.L., 1987. Service positioning through structural change. *The Journal of Marketing*.
- Simon, H., 1965. Administrative decision making. *Public Administration Review*.
- Yin, R.K., 2009. *Case study research: design and methods*, Sage Publications.

10.3

IDENTIFYING CONCEPTS FOR STUDYING IMPLEMENTATION OF INFORMATION TECHNOLOGY IN FACILITIES MANAGEMENT

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ABSTRACT

Purpose: To contribute to identifying a conceptual framework for describing and understanding the processes involved when implementing and using Information Technology (IT) in Facilities Management (FM). This paper discusses how basic concepts from different theories can be applied in parallel when studying such processes. The purpose is to enrich the empirical data collection and to widen the scope of the data analysis, thereby shedding light on central aspects of the implementation process and identifying elements in the implementation process, which should be improved in order to add value.

Background: Experiences from the FM sector indicate that IT systems meant to support FM operations and workflows often do not generate the expected added value neither to the FM department itself nor to the basic organization supported by the FM department.

Approach (Theory/Methodology): Based on findings from exciting research on IT implementation a range of more generic theoretical concepts applicable to the typical setting or situation of IT implementation in FM has been found. These theoretical concepts all clarify and describe different aspects of the implementation process and they may all be applied when designing the methodological approach for analyzing the empirical data in implementation research.

Results and practical implications: This paper, however, proposes a wider basis, compared to existing literature, for understanding implementation and use of IT in FM which may better be capable of taking into account organizational and value adding perspectives.

Research limitations: The theoretical concepts discussed in this paper are mainly generic and non-technical, and the list is not complete. Finally the concepts discussed have no direct link to the concept of added value.

Originality/value: This paper aims at demonstrating a new and more comprehensive basis for studying the IT implementation processes in FM using a wider theoretical basis than found in existing literature.

Keywords: Implementation processes, Information Technology, Facilities Management

1 INTRODUCTION

This paper introduces a range of applicable theories, concepts, models and methodologies relevant when studying the complex process of implementation of information technology in Facilities Management organizations. It frames and describes a conceivable theoretical basis for identifying methods, which can ensure added value when implementing and using IT in FM organizations.

Implementing IT in organizations involves many aspects and entities in and outside the organization such as actors/staff, the specific IT being implemented, operations, workflows, added value, organizational structure, standards and the implementation process itself. In this paper the effectiveness of the *implementation process* is assumed to be essential when striving for maximum added value. This process is therefore regarded as the most important empirical phenomenon to be studied. The focus is on the internal processes in organizations but framed in a context also including the outside environment. Jensen and Scupola (2010) conclude that organizational, technological and external environments influence the spread of IT in the FM supply chain. This paper aims at complementing the more technical and management oriented research in this area, e.g. Madritsch and May (2009).

1.1 The typical setting when implementing IT in FM

Software typically included when FM departments invest in new IT or upgrade existing IT can roughly be divided into *Data Containers* (e.g. FTP servers, databases, BIM and GIS) and *Workflow Systems* (e.g. CMMS, CAFM and IWMS). Investments in IT will often include improvements in data: Improving *interoperability* (e.g. with IFC/COBie), *transparency* (e.g. with web based GIS) and *reliability* (e.g. including data cleaning and QA procedures).

Most often existing, relatively ready for use, software solutions on the market are chosen. Some FM departments however choose to adopt systems already in use in other parts of the organization, such as ERP systems (Redlein & Zobl, 2013) or GIS. Therefore no, or only a limited, development and design phase is included. Often the main effort lies in creating and inserting data into the system and in deploying the system. Often persons from quite different professions and from different levels in the organizational hierarchy are involved, but often only a limited number of persons are involved and also only few persons are expected to use the system.

2 RELEVANT THEORIES AND CONCEPTS

2.1 Criteria for identifying relevant theories

Despite intensive research in implementation and adoption of IT during the last three decades, no significant increase in the success rate of implementation projects is observed. New ways of viewing and understanding this research area is apparently needed. A comprehensive literature review conducted by Korpelainen (2011) shows that the four dominating theories used between 1999 and 2010 in the most cited literature articles in this area were the *technology acceptance model* (TAM), *theory of reasoned actions* (TRA), *diffusion of innovations* (DOI), and *theory of planned behavior* (TPB). Korpelainen (2011) concludes inter alia that a broader view should be applied and that *socio technical* frameworks and *change management* perspectives also should be considered in future research.

Criteria for identifying the theories and concepts suggested in this paper are built partly upon Korpelainen's recommendations, but also by accepting that the theoretical concepts must be relevant and applicable to the typical setting as described above. The theories can be used in parallel and each of them is contributing a specific focus and a way of approaching, framing and investigating the different issues in implementation processes. While not assuming full coverage specific relevant concepts and models within each of the theoretical frameworks will be described in the following, and it will be discussed how each concept can be made operational, that is how it can be applied to the research methodology.

2.2 Implementation from an innovation perspective

2.2.1 Innovation Theory

The work of Joseph Schumpeter has greatly influenced theories of innovation. He argued that economic development is driven by innovation through a dynamic process in which new technologies replace the old (Keklik, 2003). An *innovation* can be regarded as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations. Four types of innovations can be distinguished between: product, process, marketing and organizational innovation (OECD, 2005).

The process of implementing IT in an FM organization can involve improvements and changes of the technology (*product innovation*) and of the work processes which the technology is meant to support (*process innovation*). The implementation process can also cause or require improvements and changes in the organization (*organizational innovation*). Parameters such as employees' educational level and the organization's support for education/training may indicate an organization's *innovation capability*. Likewise, in FM organizations the innovation strategies will also influence the innovation capability (Scupola & Tuunainen, 2011). Data on these parameters and the different types of innovations during the implementation process can be collected via interviews and longitudinal studies.

2.2.2 Diffusion of Innovations Theory (DOI)

Diffusion of Innovations Theory as described by Rogers (2003) deals with the many variables determining the rate of diffusion and adoption of innovations. DOI can be applied when studying smaller social groups, e.g. a FM department or an organization. Rogers (2003) defines an *innovation* as an idea, practice, or object perceived as new by an individual or other units of adoption – thus differing from the OECD definition mentioned above.

Some of the relevant DOI elements found in Rogers (2003) are stages and variables determining the *innovation-decision process*, variables determining the *rate of adoption*, variables related to *organizational innovativeness*, and stages in the *innovation process in organizations*. Rate of adoption variables may help predict or explain the duration of an implementation process. One such variable, which easily can be made operational, is "Complexity" belonging to the variable group "Perceived attributes of Innovations". The theory states that a high level of complexity results in a lower rate of adoption within a social group. By simply asking people involved in the implementation process how they perceive the technology being implemented, they will reveal rather precise information on complexity level (e.g. using the Likert-type scale). Another variable determining the rate adoption is "Norm" belonging to the group of variables "Nature of Social System". Norm is not as easily made operational. One cannot put the concept norm on a scale, but by studying an implementation process one may find things indicating norms among people involved, relevant for understanding aspects of the implementation process. If for instance it is perceived as acceptable and regarded as a

norm among employees to resist learning new things, this will obviously have great impact on the implementation process and can prolong the process significantly.

In DOI the diffusion and adoption process is regarded as *linear*, starting when the innovation first occurs on the agenda and ending when the whole social group being studied has adopted the innovation. DOI deals with innovations (e.g. new IT) as something static, which to some extent complies with the normal setting as described above. DOI does not take into account the interaction between people and technology and the transformation of the actors involved. For studying the *nonlinear* interaction which takes place between human actors or social groups and technology, and the transformation of the actors, sociotechnical theories can be applied.

2.3 Socio-technical understanding of implementation

2.3.1 Social Construction of Technology (SCOT)

Social construction of technology (SCOT) as defined by Bijker (1995) is a theory and a methodology within the research field of Science and Technology Studies (STS). SCOT is primarily used to map and explain development of technology from a social science standpoint. It states that technology and human actions are mutually shaped by each other. It treats technological successes and failures symmetrically, insisting on the same sort of explanation for both (Sørensen & Williams, 2002). It is by trying to understand the *context* of the social world (norms, culture, politics, economics and technology) in which the technology is embedded, one finds the explanation for a technology's success or failure (principal of *symmetry*). *Relevant social groups* with competing interpretations of available technologies (principal of *interpretative flexibility*) determine which technology is taken for granted (principal of *closure*) and chosen. In SCOT social groups are defined according to the meanings attached by the social groups to the specific technology (attributes of meanings). A social group can perceive a technology as working or not working. Each social group constructs *problems* attached to the technical artifact, which can lead to different demands and developments of a given technology (*social shaping of technology*).

According to SCOT social groups cannot be defined a priori. The researcher must start by interviewing actors involved and ask what meanings they attach to the technology. At the end of each interview one can ask which other actors are involved (snowball sampling). When no new actors are mentioned all relevant social groups has probably been detected. The actors can then be placed in different social groups according to the meanings they attach the technology.

The following example could serve as an illustration on how to apply the SCOT methodology in practice: multiple IT solutions are known to be available for supporting a specific work process in an FM department, and the actors involved decides on technology X. To better understand why technology X is chosen, and what consequences the decision may have, each actor are asked for her or his meanings attached to this technology. Technology X may be found to be energy reducing by one group of actors (social group A) and user friendly by another group (social group B) and finally impossible to learn (e.g. difficult) by a third group (social group C). One could say that group A and B find the technology operational and C finds it not operational. If group A and B can unite and override/exclude group C in the decision process, this may contribute to explaining why technology X is chosen. Now, if people in group C were meant to become the primary users of the IT system, which they found too difficult to learn, the system will quite certainly fail to be effectively adopted in the organization.

2.3.2 Actor-Network Theory (ANT)

Like SCOT Actor-Network Theory (ANT), as defined by Latour (1999), is a theory and a methodology within STS. ANT is used to study and map how actors influence each other, are connected and interact with each other. ANT follows the strategies and actions of central actors as they attempt to establish resources necessary for a project, particularly by enrolling other actors (Sørensen & Williams, 2002). In ANT a technology is an emerging and increasingly stabilized network of human and non-human (e.g. an IT system) actors (or *actants* to indicate the human and non-human nature of the entities involved). The connected actants (e.g. a FM department and an IT system) leads to a hybrid actant that does not necessarily practice the sum of the characteristics of the original actants. The objectives for investing in IT in an FM department can change considerably after the IT has been adopted. The ANT principle of *goal translation* may explain a typical situation, where the final goal (Goal 3) of connected actants (e.g. the hybrid actant “IT staff” or “staff IT”) can differ from the original goal (Goal 1) of the people involved and the *inscribed goal* or function (Goal 2) of the IT. IT systems are inscribed with the designers and programmers own ideas of how people should work and utilize the system. This is particularly important to be aware of when implementing existing and ready to use IT systems.

All actants are part of a *collective*. The FM department could be replaced by “all FM businesses” and the IT system could be replaced by “what the main suppliers of IT for FM can deliver of IT”. The responsibility for action must be shared among various actants in the collectives. An actant will always be part of one or more groups. Actants form groups called actor-networks within ANT. A group must be *deconstructed* in order to see what is going on inside.

ANT focuses on connections between actants and on how these connections are established and formed. From empirical fieldwork connections between actants can be traced and described. These connections can create hybrid actants.

For ANT truth does not exist. Truth should be understood as a state of affairs that can change over time (or *essence* can change). In the FM business, for instance, the statement that IT adds value could be regarded as true. A decade ago the same statement might have been regarded as not true. Therefor the researcher should focus on the forces that shape the essence. What made people in the FM business regard IT as value adding? What actants have been connected to shape this “goal” or understanding, and how where these actants brought together? Actions we are trying to measure are subject to *blackboxing*. An IT system can be taken for granted as a point (*punctualization*) in a sequence of actions. But alone it is a complex thing with many elements, and many actants can be involved to fix it, if it does not work. How many actants are really out there? In ANT an *intermediary* is something that does not act, but that is being acted upon. A person (an actor) uses a code (an intermediary) to get access to the IT system (could be an actor). A more operational version of the intermediary concept is discussed below.

2.3.3 Boundary Objects

A Boundary Object (BO) is a theoretical concept based on both SCOT and ANT and first defined by Star and Griesemer (1989). It is an entity (e.g. physical artifact, document, set of data, concept etc.) shared by different groups of professionals but understood differently by each group. One group does not necessarily understand the full context of use of the BO by

another social group. A BO serves as a common point of reference, mediation, conversation and negotiation. Groups of professionals involved in a process collaborate and exchange knowledge *around* BOs, which are flexible, epistemic artifacts inhabiting several intersecting social worlds and satisfying the information requirements of each of them (Star & Griesemer, 1989).

IT implementation projects in FM are most often cross-disciplinary: thereby making BOs relevant. Entities such as the project itself, the IT system or a document with the project time schedule can function as BOs. BOs may be essential for efficient collaboration and exchange of information between the different professional groups (e.g. management, consultants, FM administratives and technical staff in the FM department and future users in the organization) during the implementation process. If a BO can be identified in an IT implementation project, it can be studied how the involved groups relate to the BO, thereby shedding light on the nature of collaboration and exchange of information in the project.

Although BOs are seen to play an important role in coordinating cross-disciplinary work, boundary-spanning activities (such as face-to-face meetings, visits to each other's loci of practice, or internships) are necessary to support their role (Levina & Vaast, 2005). BOs make cross-disciplinary work possible and they perform at least three *types of work* in this context: motivate collaboration, allow participants to work across different types of boundaries and constitute the fundamental infrastructure of the activity (Nicolini, Mengis, & Swan, 2012).

2.3.4 Domestication theory

Domestication theory is also based on SCOT and ANT. It explains how foreign artifacts introduced into a preexisting context of practice gradually are "tamed" and appropriated and becomes a natural part of the (transformed) practice (Yoshinaka, 2012). Domestication of technology unfolds a series of ongoing processes or phases: appropriation, objectification, incorporation and conversion. *Appropriation* deals with the active process through which people adopt and use technology (Stewart, 2003), in other words how the technology is acquired and brought in to the context of practice. *Objectification* describes the change and adaptation of users and their environment. In general it deals with the acquisition, placement and organization of the technology in the heterogeneous context of practice and actions, and the strategies and goals concerning the technology once it has been acquired. Objectification is a process where the value by which the technology is perceived upon its appropriation is manifested (Yoshinaka, 2012). There is a multitude of strategies available for users when integrating a technology. Therefore technology will be objectified differently across different sites and practices. *Incorporation* interprets the everyday usage of the technology and shows how it comes to play its role in the practice-setting. Here the technology is integrated into practice and routines - as taken for granted. *Conversion* involves the change of meanings and values with the technology, its symbolic new value or the general impression of the technology in the practice-setting. Operationalizing domestication theory when studying an implementation process could be done by focusing on specific themes connected to each of the phases mentioned above.

2.3.5 Intermediaries

Intermediaries can be regarded as actors offering intermediation services between other actors. Intermediaries can change intent, meaning and form of technology through their acts of mediating the technology between actors (Stewart & Hyysalo, 2008). The concept of inter-

mediaries used here is a more active role in contrast to the passive role in ANT as described above.

Intermediaries between supply and use of IT play an important role in the process of implementing IT in organizations. Steward and Hyysalo (2008) explore the role of intermediaries in the development and appropriation of new technologies and deliver an operational method for mapping intermediaries. They define differences in profiles and in consequent mediating capacity of intermediaries. *Length* indicates reach between supply and use and *width* indicates content e.g. knowledge. Knowledge can flow between intermediaries.

Intermediaries can have different functions (Howells, 2006) and carry out different activities (Bessant & Rush, 1995). Bessant and Ruch (1995) identify four generic roles within these functions and roles: transfer of knowledge, sharing knowledge across user community, acting as brokering to a range of suppliers and diagnostic/innovation role in trying to identify what end users actually want. All which involve knowledge creation, translation and dissemination. Three distinct roles in social learning are fundamental different facets in the actions of intermediaries: *facilitating*, *configuring* and *brokering* (Stewart & Hyysalo, 2008).

According to Stewart and Hyysalo (2008) configuring is not only technical but also symbolic: intermediaries provide an interpretation of the product, the meanings that people give to a technology (similar to attributes of meanings in SCOT). Brokering is e.g. raising support for the appropriation process from sponsors and suppliers. Facilitating is e.g. providing the computers, the software, the training and instructions needed to use it. The experience and knowledge which they supply to the users is as important as the actual technology.

Intermediaries, their activities, role and function in IT implementation projects can be identified by interviewing the different actors involved (also the intermediaries). The snow ball sampling method can be used to identify the intermediaries. Subsequently, their niches, reach, content and flow of knowledge can be mapped. An intermediary with a short reach, a thin content and little flow of knowledge may give limited added value to the implementation process. Intermediaries may prefer certain options and suppress others and thereby, in SCOT terminology, influence the shaping of technology. Some intermediaries may try to make themselves obligatory point of passage.

A typical IT implementation project in FM can involve intermediaries such as trade associations, user groups, IT consultants, system operators, user side intermediaries who buy and pay the IT, user side intermediaries who are involved in the implementation process and help colleagues use the system, and finally user side proxy users who learn to use the system in order to teach colleagues how to use the system as end users.

2.4 Organizational structuring of implementation

2.4.1 An organizational Configuration model

According to Mintzberg (2009) an organization can consist of five *basic parts*: operating core, strategic apex or top management, middle line or supervising management, technostucture or administration and standardization, and finally support staff outside the operating core flow. The structure of an organization can be explained by using the five basic organizational *configurations models*: simple structure based on direct supervision from the strategic apex, machine bureaucracy based on standardization of work processes defined by the technostucture, professional bureaucracy based on standardization of skills defined by the operating core, divisionalized form based on standardization of outputs defined by the middle line, and adhocracy based on mutual adjustment defined by the supporting staff. Five internal *coordi-*

nation mechanisms evolve as work becomes more complicated in an organization: mutual adjustment, direct supervision, standardization of work processes, standardization of outputs and standardization of skills/knowledge. The five configurations models represents a set of five *internal forces*, exercised by the basic parts of the organization pulling an organization in five different directions: strategic apex pull to centralize, technostructure pull to standardize, operating core pull to professionalize, middle management pull to divisionalize/Balkanize and support staff pull toward collaboration and innovation in decision making.

Of special interest in regards to organizational configuration is the localization of Facilities Management within the five basic parts. This depends on the configuration of the organization and the tasks assigned to the FM department. A FM department in a machine bureaucracy, e.g. a production company, involved in maintenance of building facilities could be placed in the support staff. If the FM department is also involved in maintenance of machines used by the operation core, it could at the same time be placed in the techno structure. A FM department in a divisionalized organization, e.g. a municipality where facilitating public buildings is one of the core tasks, the FM department could be regarded as its own division in the operating core. Also of interest is which pull is activated when the FM department implements IT. When implementing a work flow system to support facilities maintenance, it could e.g. contribute to the pull from the techno structure to standardize.

2.4.2 An Organizational Diagnostic model

Several Organizational Diagnostic models used to collect information about an organization in order to establish the basis for appropriate organizational changes are available (Falletta, 2008). One of the basic, first proposed by Leavitt (1965), is the “diamond model” where the organization is conceptualized as consisting of four *interacting components*: people/actors, technology, tasks and structure. Change in one component will affect the other components, therefore requiring changes in all other components. The diamond model is a “closed system” which does not address the role of external environment (Falletta, 2008). In contrast Open System Theory offers models, where the organization is regarded as a social system dependent upon the environment in which it exist. The organization is subject to repeated cycles of input from the environment, transformation within the organization and output to the environment. The diamond model can be modified to also include other components, informal structures, and influence from the environment.

When implementing new IT a change is made in the technological component (according to Leavitt) and thereby triggering changes in the other components of the organization. Identifying which changes will occur and which changes should be made can be very complicated. One way to operationalize these premises, when studying the implementation process, could be to collect data on expected and planned changes in the organization and to observe changes during the implementation process. Discrepancy between expected, planned and observed changes may explain some of the problems which can occur during an implementation process.

2.5 Managing implementation processes

2.5.1 Project Management

Like any other project an IT implementation must be managed. Project Management can be seen as a series of phases (e.g. initiating, planning, implementing, controlling and closing), each containing different tasks connected to different themes (e.g. resources, time, cost, risk etc.) (DS/ISO, 2012, Table 1). Which phase in the project management process an implemen-

tation project has reached and to which extent the project management tasks actually are being performed is relevant for studying.

2.5.2 Change Management

Change Management deals with handling changes in organizations, such as changes inevitably taking place when implementing IT. It is a multi-disciplinary linear oriented and descriptive approach following a series of steps in the processes. A conceptual framework presented by (Hayes, 2010) involves the following main “*steps of change*”: recognizing need and start of the change process, diagnosis (review present state and identify future state), plan and prepare change, implement the change and sustain the change. In parallel with these steps issues regarding the people involved must be handled and the process must be reviewed according to planned schedule. Lewin argues that any level of behavior is maintained in a condition of *quasi-stationary equilibrium* by a force field comprising a balance of forces pushing for and resisting change. This level of behavior can be changed by either adding forces for change in the desired direction, and thereby increasing the tension, or by diminishing the opposing or resisting forces and thereby achieving a state of relatively low tension (Hayes, 2010, p. 43). Removing the restraining forces, rather than adding forces, in e.g. an organization is more likely to result in a more permanent change. Another basic concept applicable to change management is Lewin’s concept of *permanency*, which states that successful change requires three steps: unfreezing, movement and refreezing. Unfreezing means destabilizing the balance of driving and restraining forces, movement means modifying the balance of driving and restraining forces to change the equilibrium to a new state. Refreezing involves reinforcing the new state and avoiding a relapse. When studying an implementation process at a given time, is it relevant to know which step of change is being conducted and to which degree the concepts of quasi-stationary equilibrium and permanency is being applied to the management of change.

2.6 Theories specifically aimed at IT implementation

Other, in this context, relevant theoretical approaches specifically developed to study IT in organizations are Structurational model of technology, Technology Acceptance Model (TAM) and Success and failure models. TAM developed by Davis (1989) aims to predict and explain IT usage behavior, that is what causes potential adopters to accept or reject the use of IT. The two theoretical constructs- perceived usefulness and perceived ease of use- are fundamental determinants (Korpelainen, 2011, p. 14).

Structurational model of technology developed by Orlikowski (1991) is based on Giddon’s theory of structuration. The model delivers a frame for studying the relationship and influence between the three components human agents, technology and institutional properties of organizations. One important concept in this regard is the technological frame, which is a person’s assumptions, expectations and knowledge about a technology. If persons have significantly different or unaligned technological frames (incongruence) it may lead to difficulties and conflicts, when implementing the technology (Orlikowski & Gash, 1994).

Success and failure models: Most failures in IT projects can be attributed to a series of known root causes and most of the symptoms of IT project failures belong to the project management root cause (Al-Ahmad et al., 2009). In the same way, as with failures, successes in IT projects can be attributed to a series of known causes or factors that fall into a series of categories, such as system quality, information quality, information use, user satisfaction, individual impact and organizational impact (DeLone & McLean, 1992). When studying the im-

plementation process one may identify some of these elements and test whether they lead to failure or success as expected.

3 CONDENSING AND CATEGORIZING THE THEORIES

Table 1-4 contains categorized and condensed presentations of theories and concepts for studying implementation of IT in FM organizations. Applicability to research in this area and the main relevant concepts and variables are briefly explained.

Table 1: Category: Innovation / Type: Linear

Theory or concept	Main focus and idea	Applicability / Main relevant concepts and variables
Basic Innovation concepts	Economic development is driven by innovation. Innovation is the implementation of new improved artifacts e.g. technologies.	Gives focus to the innovation in the implementation process / Product, Process and Organizational innovations
Diffusion of Innovations theory (DOI)	Conditions which increase or decrease the likelihood that an innovation will be adopted by a given culture, and conditions determining the rate of adoption	Range of variables can be used to explain the rate of which the IT is adopted in the FM organization / Variables determining the innovation-decision process, rate of adoption and organizational innovativeness

Table 2: Category: Sociotechnical / Type: Non-linear

Theory or concept	Main focus and idea	Applicability / Main relevant concepts and variables
Social Construction of Technology (SCOT)	Formalizes steps and principles to follow when analyzing the causes of technological failures or successes. Technology is shaped by humans.	Framework for understanding the choice and development of IT and the human interaction with IT / Social groups, Attributes of meanings, Interpretive flexibility.
Actor Network Theory (ANT)	For mapping how human and non-human actors influence each other, are connected and interact.	Mapping the actants involvement and interconnection. Can give insight in the translated goals of the hybrid actors / Actants, Connections and Goal translation
Boundary Objects	Entities shared but understood differently by different social groups and used for collaboration and exchange of information.	Observing the use of BOs can give insight in collaboration and knowledge exchange between disciplines and social groups involved / BOs and types of work
Domestication theory	Deals with how foreign artifacts introduced into a preexisting context of practice gradually can become a natural part of the (transformed) practice.	Frames the process with focus on usage, values and meanings of the IT / Appropriation, Objectification, Incorporation and Conversion.
Intermediaries	Intermediaries are actors offering intermediation services between other actors, e.g. passing on knowledge.	Identifying the intermediaries and mapping how the organization gains access to knowledge / Functions, Activities, Roles. Facilitating, Configuring and Brokering.

Table 3: Category: Organizational / Type: Diagnostic and Configuration models

Theory or concept	Main focus and idea	Applicability / Main relevant concepts and variables
Leavitt's Diamond	Maps the interaction between main components in an organization. A change in one component causes (and requires) changes in all other components.	Discrepancy between expected, planned and observed changes may explain problems that can occur during the implementation process / Organizational components: Technology, Tasks, Actors and Structure
Mintzberg's organizational configuration framework	Defines basic parts that constitute an organization according to standard categories. Different internal forces pull the organization in different directions.	The FM department's involvement in the organization can be depicted and understood in the model. Internal forces caused by the IT being implemented can be explained / Basic parts, Coordination mechanisms, Configuration models and Internal forces

Table 4: Category: Management / Type: Prescriptive and partly Linear

Theory or concept	Main focus and idea	Applicability / Main relevant concepts and variables
Project management	Predefined project management phases with tasks connected to themes	The degree to which the phases and tasks are being conducted can be mapped / Phases, Themes and Tasks
Change management	Predefined steps for managing changes in organizations.	The phase and the handling of the implementation can be mapped and explained / Steps of change, Quasi-stationary equilibrium and Permanency

4 IMPACTS ON THE EMPIRICAL STUDIES

The theoretical framework, concepts and variables described in this paper provide guidance and focus areas for collecting empirical data, in the research area of IT implementation in FM. The framework establishes theoretical concepts in which the empirical data can be fitted when being collected and analyzed. The concepts can be used as basis for the coding process. Finally they deliver the lenses by which the empirical data can be analyzed and understood.

5 CONCLUSION

This paper proposes a basis for understanding implementation and use of IT in FM which may be capable of taking into account organizational and value adding perspectives. This paper shows that varying theories complement each other as necessary approaches and methodologies to apply when studying the complex processes of implementing and using IT in FM.

REFERENCES

Al-Ahmad, W., Al-Fagih, W. et al (2009). A taxonomy of an IT project failure: Root causes. *International Management Review*, 5(1), 93-104.

- Bessant, J., & Rush, H. (1995). Building bridges for innovation: The role of consultants in technology transfer. *Research Policy*, 24(1), 97-114.
- Bijker, W. E. (1995). *Of bicycles, bakelites, and bulbs. toward a theory of sociotechnical change*. Cambridge, MA: MIT Press.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319-340.
- DeLone, W., & McLean, E. R. (1992). Information systems success: The quest for the dependent variable. *Information Systems Research*, 3(1), 60-95.
- DS/ISO. (2012). *DS/ISO 21500. vejledning i projektledelse, guidance on project management*. København: Dansk Standard.
- Falletta, S. (2008). *Organizational diagnostic models, A review & synthesis*. . Sacramento CA: Leadersphere.
- Hayes, J. (2010). *The theory and practice of change management* (3rd ed.). Basingstoke: Palgrave Macmillan.
- Howells, J. (2006). Intermediation and the role of intermediaries in innovation. *Research Policy*, 35(5), 715-728.
- Jensen, P. A., & Scupola, A. (2010). ICT adoption in the danish facilities management supply chain - what are the factors that matter?
- Keklik, M. (2003). *Shumpeter, innovation and growth, long-cycle dynamics in the post-WWII american manufacturing industries*. England: Ashgate Publishing Limited.
- Korpelainen, E. (2011). *Theories of ICT system implementation and adoption - A critical review*. Aalto University publication series SCIENCE + TECHNOLOGY, 9/2011: Aalto Print Helsinki.
- Latour, B. (1999). A collective of humans and nonhumans. *Pandora's hope : Essays on the reality of science studies* (pp. 174-198). Cambridge, MA: Harvard University Press.
- Leavitt, H. J. (1965). Applied organizational change in industry: Structural, technical and humanistic approaches . In J. G. March (Ed.), *Handbook of organizations* (pp. 1144)
- Levina, N., & Vaast, E. (2005). The emergence of boundary spanning competence in practice. implications for implementation and use of information systems. *MIS Quarterly*, 29(2), 335-363.
- Madritsch, T., & May, M. (2009). Successful IT implementation in facility management. *Facilities*, 27(11), 429-444.
- Mintzberg, M. (2009). *Structure in fives. designing effective organizations*. Edinburgh: Pearson Education Limited.
- Nicolini, D., Mengis, J., & Swan, J. (2012). Understanding the role of objects in cross-disciplinary collaboration. *Organization Science*, 23(3), 612-629.
- OECD. (2005). *Guidelines for collecting and interpreting innovation data, 3ed edition, oslo manual*. OECD Publishing.
- Orlikowski, W. J., & Gash, D. C. (1994). Technological frames - making sense of information technology in organizations. *ACM Transactions on Information Systems*, 12(2), 174-207.
- Orlikowski, W. J. (1991). *The duality of technology : Rethinking the concept of technology in organizations*. Cambridge, Mass: Massachusetts Institute of Technology.
- Redlein, A., & Zobl, M. (2013). ERP systems within facility management. *The 2nd Year of Advanced Research in Scientific Areas* , 153-155.
- Rogers, E. M. (2003). *Diffusion of innovations*. NY: Free Press.
- Scupola, A., & Tuunainen, V. K. (2011). Open innovation and role of ICT in business-to-business services: Empirical evidence from facility management services. *Proceedings of SIGSVC Workshop . Sprouts: Working Papers on Information Systems*, 11, 158.

- Sørensen, K. H., & Williams, R. (2002). *Shaping technology, guiding policy : Concepts, spaces and tools*. UK: Edward Elgar.
- Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in berkeley's museum of vertebrate zoology, 1907-39. *Social Studies of Science*, 19(3), 387-420.
- Stewart, J. (2003). The social consumption of information and communication technologies (ICTs): Insight from research on appropriation and consumption of new ICTs in the domestic environment. *Cogn Tech Work*, 5, 4.
- Stewart, J., & Hyysalo, S. (2008). Intermediaries, users and social learning in technological innovation. *International Journal of Innovation Management*, 12(3), 295-325.
- Yoshinaka, Y. (2012). *Lecture notes on domestication of technology*. DTU course 42640 sciotechnical design. DTU, Copenhagen.

CHAPTER 11

CASE STUDIES

RESEARCH PAPERS IN PRACTICE TRACK 1

11.1

Benchmarking of FM Departments of 8 Scandinavian Hospitals

Håkon Kvåle Gissinger and Marit Støre-Valen

11.2

Effective Facility Management and Operations via a BIM-based Integrated Information System

Pouriya Parsanezhad and Johannes Dimyadi

11.1

BENCHMARKING OF FM DEPARTMENTS IN 8 SCANDINAVIAN HOSPITALS

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ABSTRACT

Purpose: To test if Balance Score Card (BSC) methodology can be a simple and suitable method for mapping competence and maturity level for benchmarking purposes and to study whether its' a connection between the quality of three service products and the competence and skills within the hospitals FM organisation.

Background:

The European hospital sector is constantly changing, and the demand for hospital services is rapidly increasing. The grow rate in the demand is far higher than what governmental budgets can cope with. Increased effectiveness in the hospital sector will contribute to reduce the gap between the demand and the supply side in hospital sector.

Approach:

To enlighten the importance of FM in hospital sector, the NordicFM network took in 2010 the initiative to a benchmarking project between 8 Scandinavian hospitals, with the objective to measure the product quality of three products; cleaning, food for patients and hospital logistics. In parallel with the NordicFM Benchmarking project, a follow up research on the FM organisation of the participating hospitals was carried out.

Results: The analysis shows fairly better results in Swedish hospitals than in the other Scandinavian countries. There is an indication that there is a correlation between the product quality and the skills and competencies of the FM organizations. The BSC method to collect information about the FM skills is found to be useful for benchmarking purposes in an early phase.

Practical implications: The research shows a practical and efficient way to collect information in an early phase in a benchmarking process.

Research limitations: The research is based on the subjective information given from the leader of the FM department. The data collection is too small to be able to generalize the findings to be true for the whole sector. Also the indication that there is a correlation between competence and service quality is to be expected but further research and more data must be collected in order to be valid.

Originality/value: This study presents data for a benchmarking process of 8 Scandinavian hospitals on the quality of three service products and gives an indication on the variety between the quality and the competence level against best practise.

Keywords: Facility Management, Benchmarking, Hospital sector, Balanced Scorecard, FM product quality

1 INTRODUCTION

The European FM model (EN 15221-1), illustrate the vital concept of how the demand side needs for service delivery connects to a service provider (internal or external) who delivers the services needed.

In the hospital sector, there is a long tradition for dividing the sector in a “clinical part” (core business) and a “non-clinical part” (support business). In the european fm context the “non-clinical part” organizations will have be found in the right hand side of the fm model (en15221-1). The internal fm departments have the responsibility to deliver multiple services, highly integrated. To be as effective as possible in delivering hospital service, high product quality from fm departments integrated support service deliverables is an important critical success factor.

Fm, as an own professional discipline, has through the last two decades developed from a practical discipline towards a recognized research field. Adding value for core business is a vital goal of the professional fm delivery. That is pointed out by european researchers in jensen et al (2012) that presents the concept findings and perspective on the added value of facility management from the most important work of vital members of the eurofm research network group from the recent years. Most of the literature review for this paper is drawn from this review.

For measuring the actual performance of the individual fm departments against a “best practice” score, the definition of a baseline for “best practice” is based on the findings from the literature (Jensen et al, 20012).

The literature gives examples and addresses other important fm aspects such as:

- Vital properties that define FM as a profession in a European context.
- Examples of different “best practice” performance
- Examples on how FM as a profession discipline contributes to add value from core business.

Similar discussion and examples is found in the textbook of Atkin and Brooks (2009).

This paper presents two datasets. One comes from a Nordic benchmarking project of 8 hospitals, with the objective to benchmark the product quality of three specific service deliveries. The other dataset is an extended quality study done by the author, looking at the skills and maturity level of the same FM departments.

The two datasets are considered independent. In this paper we compare the two individual datasets, and address the following research questions:

1. What are the major differences between the participating hospitals in organisational skills and competencies documented by the questionnaire from Dataset A?

2. Is there any correlation between the NordicFM scoreboards (Dataset B) on product quality and the score drawn from the questionnaire on organisational skills and competencies (Dataset A)?
3. Is the use of balanced scoreboard a useful way to collect information in an early phase of a benchmarking process?

2 STATE OF THE ART

FM focuses on adding value for core business. Quite a few publications in FM research have focused on how to measure the added value. A major trend in the European hospital sector is the use of Diagnostic Related Grouping system (DRG) as an important component in the financing system. The basic concept of the DRG point is actually a direct value mapping.

There has also been carried out different work when it comes to value classification. One example of resource classification is the use of space. Norwegian Directorate of Health (Helsedirektoratet, 2009) has developed a space classification system that is normative for the Norwegian health care sector. The classification system divides the different generic spaces into the categories: normal care, intensive care; operation theatre and so on (Helsedirektoratet, 2009). The European standardization work has resulted in a new standard defining relevant FM processes (EN 15221-5). Several of the relevant processes for the European FM sector will be found in the standard, but the more specific services such as patient food and sterile goods is not part of the standard.

In Germany researchers have been working on identifying the FM processes in the hospital sector. Lennerts et al (2004) found 29 FM processes that is relevant for German hospitals. This is further developed by Diez (2009) that shows a model that seize to make a direct connection between the DRG points and the cost of some of the identified FM processes. Able et al (2006) in their paper asking: "How much FM needs a hospital?" as a relevant question researched in order to find best practice. Able et al (2006) mainly describes the ongoing OPIC research project where they formulated the overall thought-provoking question as "Does the patient or the doctor set the demand for FM?"

There is expected that there will be a connection between the quality of an FM product and the competence and maturity level in the FM organization. Valen and Olsson (2012) found this to be true in their study among more than 30 Norwegian municipalities. They looked at the technical condition and maintenance backlog of the building stock and the FM competence and maturity within the FM organization.

However, the main purpose of this paper is to see whether BSC methodology is a suitable method for collecting information about competence and maturity for a benchmarking purpose.

3 METHODOLOGY APPROACH

The extended study on skills and maturity level was based on in-depth interviews with a questionnaire with 60 questions. The questionnaire was developed based on the primary sources of literature. All the questions were formulated as imperatives, and the respondent answered the question at a five point scale:

Always (A) ; Frequently (F) ; Occasionally (O) ; Seldom (S) ; Never (N)

The respondents were the FM leaders at their respective FM department in the 8 hospitals. This dataset is referred to as “Dataset A”, collected by the author. The two first interviews were carried out in connection with the workshop on the NordicFM hospital project in Copenhagen, November 10th, 2011. The six other interviews were carried out as telephone interviews during the time period December 2011 to January 2012. The questionnaire was sent to the respondent up front of the interview, written in English language. The interviews were carried out in Scandinavian language and the questions were simultaneously translated into Scandinavian language when interviews were performed.

The 60 questions were grouped in the four focus areas; *Customer, Financial, Operational, Interaction*. For each answer on of the 60 questions, the respondent is given a score of 0, 1 or 2 points depending on how far the answer was from “Best Practice”.

In the main Nordic benchmarking project, a vast amount of data was collected and analysed by Ernst and Young (EY). This dataset is referred to as “Dataset B” (NordicFM, 2012).

Both Dataset A and Dataset B, are designed by using an analysis technique inspired by the Balanced Scorecard methodology (Kaplan and Norton, 1996). Behind the questions for the two datasets, a scoreboard was set up which rates the fixed answers on a predefined scale. The predefined scale is measuring against a set “Best Practice” scores found from the literature review. While Dataset A seizes to evaluate the skills and competence to the participating FM departments, Dataset B seizes to evaluate the product quality for 3 different service products.

Methodology NordicFM main project (Dataset B)

The Nordic Benchmarking project was checking the quality of three service deliveries: *Cleaning, food for patients and hospital logistics*. The quality measure was levelled against an indicator set developed by EY to capture and analyse the three products. The indicator set is protected with individual property rights and will not be published here. Only a brief description of how they collected the data are presented (NordicFM, 2012):

Each of the three products is checked through the following three dimensions

- Cost
- Service level
- User Satisfaction index

The cost data was drawn from the accountant system through a rigorous template structure. For the product “Material supply”, the cost analysis is lacking, due to the fact that the EY’s template structure for gathering cost data were not fully developed before the execution of the Benchmarking project. The User satisfaction index is based on a simple inquiry with 8 questions that were passed out to a selection of 100 patients and 100 medical staff in each of the participating hospital. Selections were carried out in the way that the inquiry was asked to the first 200 persons met in the corridor of each hospital on a specific date.

The service level score is a result of EY's evaluation of a combination of qualitative and quantitative data drawn from structured interviews on key personnel from the FM organizations in each hospital in combination with facts from the cost analysis.

The weighting of the score between the three dimensions were 50 % for the cost and 25 % each for the service level and user satisfaction.

The indicator set was developed and improved of EY by a benchmarking process of 40 Swedish hospitals in 2009. The score from the Benchmarking of the 8 Scandinavian hospitals are compared with the Swedish average in the main report from the NordicFM benchmarking project (NordicFM, 2012).

Questionnaire design (Dataset A)

The Balances Scorecard methodology (Kaplan and Norton, 1996) is a concept with multi-dimensional analysis on organisations results. The methodology is developed based on the idea that to assess the organisation performance by looking at the financial figures will not be adequate in knowledge economics. Consequently, more facets are needed to enlighten the overall organizational performance. Facility Management is about producing services where the product quality (service level) in nature is hard to quantify. Multi-dimensional measurement e.g. customer satisfaction index, and different types of qualitative measurement for product quality is common in the FM business.

The use of Balanced Scorecard Methodology has some weaknesses in scientific work. One of the major challenges is to establish a baseline to measure the answers against. Other challenges are the weighting of the different partial scores to a grand total score. Finally it might be difficult to interpret the results and draw conclusions from the different scores. When using the scorecard in a benchmarking process, the major point is to find similarities and differences between the different participants. The overall "Best Practice" score will be of less importance (since the relative difference between the participants is what you are seeking). There is still a major risk that the scoreboard will be biased by the personal opinion of the developer of the scoreboard. However, as a benchmarking tool that can be rather useful since the actual score is of less important than measuring the relative difference against other practises.

Scoreboards are commonly developed through an iterative process aiming to develop a common understanding of "Best Practice", and thus, which score to use. The scoreboard for Dataset A that is presented in this paper, is developed by the author alone. The original intention for developing the scoreboard was to develop and refine the questions and scores by discussing the questionnaire between the participants in the NordicFM benchmarking project, but from various reasons such discussions were not able to carry out. As a consequence, the question and scores from Dataset A, will be a product of author's considerations alone. Some important consideration made by author, when developing the scoreboard is commented in the following paragraphs.

The four dimensions

The choice of the four dimensions will always be a matter of question since other "candidates" for focus areas could easily been chosen. However, the four dimensions is recommended by the work of Atkin and Brooks (2009) that has good experience with these dimensions. They argue for why these four dimensions may be good candidates for measuring FM

skills and maturity. To cite their own evaluation of the method, Atkin and Brooks (2009) found that *“The four perspectives have shown themselves to be purposeful and aligned to both the facilities management strategy of organisations and their strategic business objectives”*.

The selection of the specific four dimensions, also find support in other recent publications. EN 15221-2 “Guidance on how to prepare Facility Management agreements” has a “client centric” approach. Hence this will justify why one dimension should be “Customers”. In later part of the standard the controlling activity is stressed as a vital tool for “Financial control”.

The “Operational” dimension is defined by Atkin and Brooks (2009) to be as *“how efficient and effective is the delivery of estates related and facilities services?”*. The questions in this section focus on the tactical tools like benchmarking, market testing, risk analysis, procurement strategy and so on. All different tools that are recommended in recent FM reports and books. The last focus area “Interaction – how does the facilities management function continue to improve and assist the core business” was the main theme on the EuroFM conference in Vienna in 2011 called “Cracking the productivity nut”. The importance of this fourth dimension is then obvious (EuroFM, 2011).

The weighting

The score on each question is set from a base level based on the author’s apprehension of what is “Best Practice”. In some cases the answer is obvious. For example question 3.12:

“We have the competence needed to handle the demands in the Health and security legislation”

Health and security should always be dealt with in a proper way and hence the score on this question is 2 points for the answer “Always”, and 0 points for the 4 other alternatives.

In other cases the score on a single question, will be more controversial based on the different opinions among the author and the respondent, and heavily influences on different organisational models. The fixed score will pretty much be interpreted as a “one size fits all” thinking. This paper may be considered as action research aiming to work together with the different respondent to search for “Best Practice”. The questions and the scoreboard should be considered as a pilot study aiming to search for Best Practice, which make the score itself less important compared with the chosen questions and the subsequent discussions among the participants that may arise in the later phase of this research work. The above may be illustrated with the question 3.2

“We look at dedicated personnel in the customer’s organization as internal service providers, and give them credit for their work”

The given score for this question is “Always” = 2 points, “Frequently” = 1 point and 0 points for the three other alternatives. If your strategy is to have a well defined borderline between core/noncore processes, you will expect that leaving part of the process to the core business will conflict with your strategy and thus you are expecting the choice “Never” to give 2 point and “Seldom” to give 1 point.

During the interviews both point of views on what is “Best Practice” were represented. FM in hospitals consists of a broad specter of highly integrated processes. In the scoreboard the number of questions considering the different process and consideration will vary. The number of questions on each subject will impact on the final result. Finally when setting up the scoreboard, author stressed to place the scores in random order to avoid that some specific answers e.g. “Frequently” would give the highest score. This consideration made it less possible that the respondents answered consequently “by chance” and ended up with a better score than respondents that strived to give their answers so “honest” as possible.

4 RESULTS

The respondents in this research are one representative from each of the FM department of the eight participating hospitals in the NordicFM hospital benchmarking project. The participating hospitals show great variety in size and areas of specialization. All the hospitals have an emergency function. Some key figures from the participating hospitals is presented in Table 1.

Table 1: Key figures for the participating hospitals

	Country	Turnover	Currency	Beds	Operations	Patient nights	Day treatment
Hillerød Hospital	Denmark	1,9	bill DKK	454	44 000		225 000
Rikshospitalet	Denmark	6,7	bill DKK	1200	50 000	350 000	450 000
St. Olavs Hospital	Norway	6,9	bill NOK	973		338 507	512 374
Helsingborgs lasarett	Sweden	2,2	bill SEK	400	17 000	152 000	
Länssjukhuset i Kalmar	Sweden	1,8	bill SEK	414	11 000	119 000	432 000
Jönköpings län	Sweden	3,5	bill SEK	465	13 000	156 000	
Sørlandssykehuset	Norway						
Bispebjerg Hospital	Denmark	1,8	bill DKK	466	35 000	160 000	330 000

All the eight respondents were FM leaders from the FM department in the hospital. The departments have responsibility for most of the 30 processes as defined by Diez (2009) with exception for IT, and some minor supplementary processes. One of the respondent that was from Jönköping’s county did not have responsibility for the building operation and technical installations, and contacted one of his colleagues, to get the answers for the building related questions.

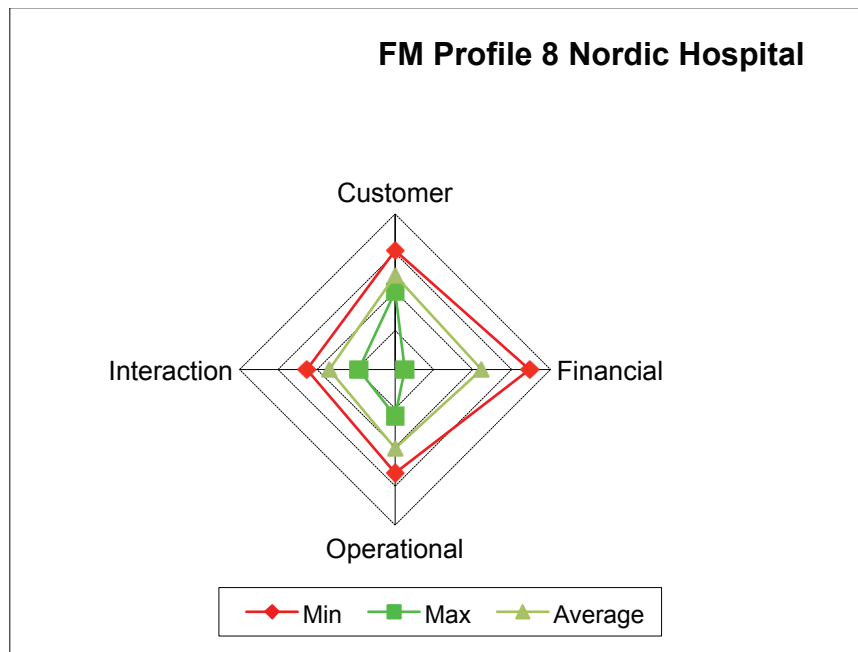
Results

The radar profile from the interview grouped in min-max-average score is presented in Figure 1. As we can see from the radar diagrams the greatest span between the score among the participants seems to be greater on the financial dimension then on the tree other dimensions, but the score on the operational dimension also seems to vary to a great extent. The overall lowest score is on the Interaction dimension.

The “Best practice score” is to a high extent drawn from Atkin and Brooks (2009), where strong focus was put on the financial following up through the procurement process. All the respondents in this research are in-house FM suppliers, and the use of sub-contractors is very limited. The spread along the finance dimension may be explained with variety of focus due

to the minor importance of good following up of sub-contractors (due to the limited impact on the overall performance of the FM supplier's organization).

Figure 1: Spread of results from the eight participating hospitals



What is more surprisingly is the great spread in the dimension “Operation”. Traditionally the internal FM supplier's organization has been developed from a day-to-day operational focus where Health and Security have had main priority. The gap between the actual score and “Best Practice” is kind of surprising. A major part of the total “Operational” score is the Health and Security aspects. The score points on Health and Security questions (3 of 15 questions have only used the score 2 points for always, and 0 points for the four other alternatives). If a respondent, choose the answer “often” on these three question this will have great negative impact on the total score along the “operational dimension”

The relatively lowest average score along the “Interaction” dimension were expected due to the traditional conservative split between clinical and non-clinical personnel in the hospital “world”.

The overall highest average score is on the customers focus. This finding is very promising for future work in the benchmarking process and the subsequent following up activities since customer focus is considered to be one major driver towards Best Practice in FM.

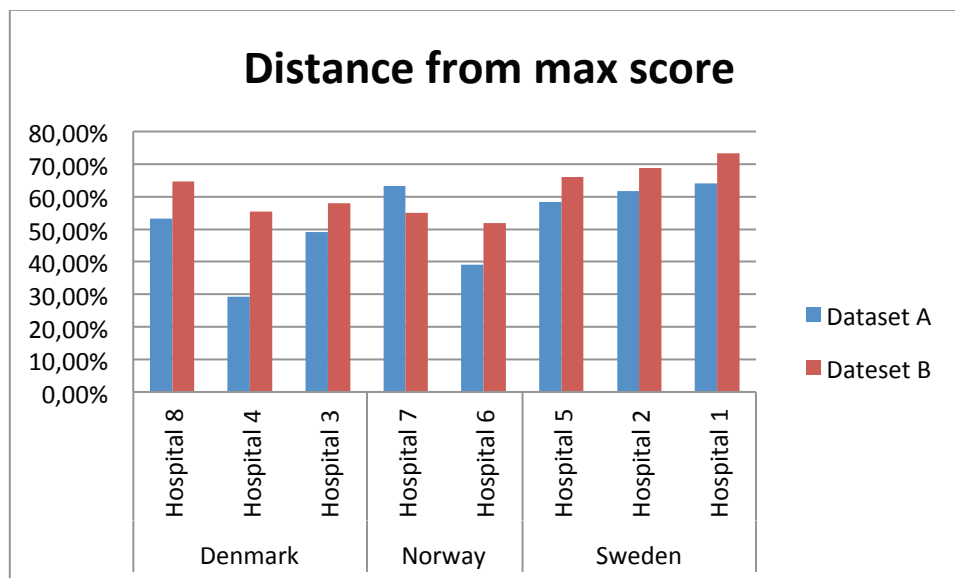
Comparison with NordicFM main project (Dataset B)

While the questionnaire is checking the FM supplier's organizations towards “Best practice”, the NordicFM Benchmarking project is checking product quality. Both datasets have a fixed max score. Calculation of the relative difference from the highest possible score from the two datasets, gives the following result.

Table 2: Relative score from the eight participating hospitals, Dataset A and Dataset B

	Hospital 8	Hospital 7	Hospital 6	Hospital 5	Hospital 4	Hospital 3	Hospital 2	Hospital 1
Dataset A	53 %	63 %	39 %	58 %	29 %	49 %	62 %	64 %
Dateset B	65 %	55 %	52 %	66 %	55 %	58 %	69 %	73 %

Figure 3: The relative distance from max score for the two independent dataset



One interesting finding from this graph is that the Swedish hospitals seem to achieve the best score for both Dataset A and for Dataset B. The scores from the graph also indicate that there might be a correlation between the two datasets. However the selection of data is too small for statistical analysis, and this indication should be further researched and tested with more data. However, there is an interesting indication that we can reflect on a bit further.

The Swedish hospitals were participating in the EY Benchmarking for the second time in 2010. In 2009 data from 43 Swedish hospitals were reported and analyzed by the same template structure by EY. The findings from the 2009 data were used to implement different improvements projects.

The FM marked in Swedish public sector is recognized to be more mature then in Denmark and Norway. FM as a concept may be more well recognized business area among the Swedish participants, and may explain why they score better on the questions about skills and maturity (Dataset A).

The indication of a possible higher score measured in both datasets for Sweden in comparison with the two other countries is a finding that should be more thoroughly investigated in following up research. The possible correlation between skills and competencies in the FM-organizations, measured by (Dataset A) and the score for the product quality delivered from the same organization (Dataset B) is also interesting further research.

5 PRACTICAL IMPLICATIONS

FM is defined as “integration of working processes”. The possible correspondence between the scoreboard from the questionnaire (Dataset A) and the EY score for product quality in the NordicFM project (Dataset B) should be more thoroughly investigated in future research. If a possible link exists between organizational behavior, and product quality, more or better FM products will be possible to achieve by training the different FM organizations in their skills and ways to organize their daily work.

6 CONCLUSION

Benchmarking is a vital part in the professional field of FM. The “ticket” for participating in a benchmarking club may be considered as expensive both in form of direct cost and internal workload.

This paper gives an example of practical use of a simple tool for benchmarking. Some interesting possible connections have been shown. The findings have the potential of being useful in the earliest phases of a benchmarking process for example in the search for focus areas in the benchmarking process.

The understanding of FM as an own discipline is still under development. Major part of the FM literature is about FM in office buildings. “Best Practice” of FM in hospital buildings might differ from FM in office buildings to a certain extent. In future work more efforts should be put on future development of the questionnaires and the scoreboard to support a more common understanding of “Best Practice” of FM in hospital buildings.

REFERENCES

- Abel, Jochen, Diez, Karin and Lennerts, Kunnibert (2006) How much FM needs a hospital, In Proceedings from CIB W70 conference in Trondheim 12-14 June 2006
- Atkin, Brian and Brooks, Adrian (2009), Total Facilities Management, Second edition, Blackwell publishing Ltd
- CEN EN 15221-1 Facility Management - Part 1: Terms and definitions, 2006.
- CEN EN 15221-2 Facility Management - Part 2: Guidance on how to prepare Facility Management agreements, 2006.
- CEN EN 15221-5, Facility Management - Part 2: Guidance on how to prepare Facility Management agreements, 2011.
- Diez, Karin (2009) Ein prozessorientiertes Modell zur Verrechnung von Facility Management Kosten am Beispiel der Funktionsstelle Operationsbereich im Krankenhaus (In German), Universitätsverlag Karlsruhe, 2009, ISBN: 978-3-86644-386-0
- EuroFM (2011) Conference program 2011, available online <http://eurofm.org/library/efmc-2011-updated-program-may-9/updated-efmc-2011-program-may-9-.pdf>
- Jensen, P. A. , van der Voordt, T. and Coenen, C. (2012) The Added Value of Facilities Management – Concept , Findings and Perspectives, Polyteknisk forlag, ISBN-13 9788750210405
- Helsedirektoratet, Veileder klassifikasjonssystem for sykehusbygg, v 2.0 Dato: 21.05.2009
- Kaplan, R. S. and Norton D. P (1996) The balanced scorecard: translating strategy into action. Boston, MA: Harvard Business School Press

- Larssen, Anne Kathrine (2011) Bygg og eiendoms betydning for effektiv sykehusdrift (In Norwegian), PhD thesis, Norwegian University of Technology and Science, Department of Civil and Transport Engineering.
- Lennerts, K., Abel, J. and Pfründer, U. (2004) Space as a cost producing unit in hospitals, in proceedings from EuroFM research symposium in Copenhagen 12-14 May 2004.
- NordicFM (2012) Report from the NordicFM benchmarking project, available online: www.NordicFM.org
- Valen, M. S., Olsson, N. O. E. (2012) How are we heading towards mature facilities management in Norwegian municipalities?, *Journal of Facilities Management*, vol 4, no 10.

11.2

EFFECTIVE FACILITY MANAGEMENT AND OPERATIONS VIA A BIM-BASED INTEGRATED INFORMATION SYSTEM

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ABSTRACT

Purpose: The purpose of this paper is firstly to summarize the status quo of the building information management technologies applied in the facility management and operations (FM&O) sector and identifying prevailing issues; and secondly, to devise technical solutions for those issues based on an exemplar case.

Background: Considerable financial losses could occur as the result of insufficient interoperability issues among information systems. In order to minimize losses, Building Information Management (BIM) tools must be able to interoperate with a variety of digital FM&O systems.

Approach: This research applies the principles of grounded theory as well as conceptual constructs of a proposed BIM framework. Firstly, descriptions of information management systems of eleven projects in technical reports are analyzed and the prevailing technical issues extracted. Then, a narrative representation of an IT-implementation project together with its organizational context has been provided. Finally, the most important issues from recent projects have been presented together with their respective solutions provided by the case project.

Results: The results demonstrate that the most important issues in implementing BIM for streamlining FM&O activities are lack of guidelines and efficient technologies for capturing BIM models of existing facilities, coping with non-consistent terminologies and taxonomies, requirements specification in BIM applications, and identifying which information and what levels of detail are desired by the FM&O teams.

Practical implications: In addition to scholars, the results are useful to database implementers and database designers, as well as decision-making buddies in the FM&O sector.

Research limitations: More research in this area is needed with a focus on business processes and regulatory requirements.

Originality/value: No earlier research has so thoroughly described the overall architecture and functionalities of different components of an integrated BIM FM portal solution with regard to the latest findings in both theory and practice.

Keywords: BIM FM, Facility Management, FM&O, Building Information Modelling, Interoperability

1 INTRODUCTION

Facility managers of corporations are responsible for the operation and maintenance of assets. This constitutes a considerable share of their annual expenditures. In the building industry, 85 percent of life-cycle costs of a facility occur post construction (Jordani, 2010). Accessibility of the required information is essential to any efficient facility management and operations (FM&O) practice (Teicholz, 2013) i.e. lack of information dramatically lowers the efficiency of maintenance activities (Motawa & Almarshad, 2013).

In recent years, Building Information Management (BIM) technologies have substantially influenced information management practices throughout the entire building industry. BIM has demonstrated potential for tackling problems induced by insufficient access to information in all phases including FM&O (Sabol, 2008). Facility owners are now pursuing a variety of business objectives by using BIM including but not limited to reducing operating and maintenance costs, improving service delivery, streamlining business processes, underpinning and optimizing future building modifications, and consequently achieving higher return-on-investments (ROIs) (Aspurez & Lewis, 2013; Teicholz, 2013; Eastman, Teicholz, Sacks, & Liston, 2011; Khemlani, 2011; Jordani, 2010; Ding et al., 2009).

Nonetheless, there are three major obstacles against leveraging BIM for FM&O in its full capacity, namely IT provisions, business processes, and contracts (Parsanezhad & Tarandi, 2013; E. W. East, Nisbet, & Liebich, 2013). The three categories correspond to the three industry foundations constituting the IFC (Industry Foundation Classes) standard which are articulated by Owen (2009) as technologies, processes, and people, as well as the three fields of activity formulated in the BIM framework developed by Succar (2009), i.e. technology, process, and policy.

This paper is a qualitative work that is based on the principles of grounded theory. It mainly addresses how the first obstacle (IT provision) can be overcome. A summary of the literature on implementation of BIM for FM&O is provided, an example of such systems is described, and its components and functionalities are analyzed in relation with the findings of the literature review. The purpose of this paper is twofold: firstly, to summarize the status quo of the building information management technologies applied in the facility operation activities and identifying prevailing issues and impediments; secondly, to devise technical solutions for those issues based on an exemplar cutting-edge case.

2 STATE OF THE ART

2.1 Technological BIM FM integration solutions

Considerable financial losses occur as the result of insufficient interoperability issues among information systems in the building industry. A substantial proportion of these losses is attributable to the FM&O sector (NIST, 2004). Owners are willing to use BIM to enhance their operation and maintenance activities and to minimize or eliminate losses (Jordani, 2010). BIM-enabled information systems are aimed to seamlessly convey the information from design and construction models and databases to actors within the FM&O sector. Such systems

must be capable of interacting with other digital tools that are already used in the sector. FM&O staff work with a variety of tools ranging from paper and pencil to spreadsheets, Computerized Maintenance Management Systems (CMMS's), Computer-Aided Facility Management (CAFM) tools, Document Management Systems (DMS's), Building Management Systems (BMS's), Building Automation Systems (BAS's), etc. (Lewis, 2013a; Jordani, 2010).

CMMS's are deployed for asset management, generation of service requests, managing work orders of different types, calculating/tracking required/used resources for planned/executed jobs, keeping employees records, and inventory of managed assets (Sapp, 2013; Lewis, 2013a). FAMIS (by Accruent), IBM Maximo, Corrigo, WebTMA (by TMA Systems), and AiM Maintenance Management (by AssetWorks) are some commercial example of CMMS's. FAMIS uses an ORACLE database which is integrated with financial databases (Aspurez & Lewis, 2013).

CAFM systems are a combination of Computer-Aided Design (CAD) and relational database software aimed for space management i.e. administering room numbers, departments, usable heights, room areas etc. (Sapp, 2013; Lewis, 2013b; B. East, 2013). Most contemporary CAFM systems still acquire manual querying and updating routines such as overlaying polygons on drawings (Aspurez & Lewis, 2013). FM:Interact (by FM:Systems), Archibus, and AiM Space and Facilities Management (by AssetWorks) are some commercial examples. Despite the widespread acknowledgement of advantages of implementing BIM technologies for operating facilities, the adoption of as-built BIMs within FM&O is still more a vision rather than a reality (Teicholz, 2013). This is partly attributed to the large variety of CMMS's, CAFM systems, and DMS's. Sporadic examples of such adoption have nevertheless emerged in recent years namely the Revit-compatible version of Archibus (Jordani, 2010).

The cutting edge technical solutions in the field can be categorized as seen in Table 1 (after Teicholz, 2013; Lewis, 2013a). Construction Operations Building information exchange (COBie) is an open data transfer specification developed by the U.S. Army Corps of Engineers which facilitates delivery of managed asset information by using low-level formats such as the Excel spreadsheet (E. W. East & Carrasquillo-Mangual, 2012; Sabol, 2008). In Table 2, a number of real-world applications of the above initiatives are briefly introduced.

Table 1: Today's technical solutions for optimizing information transfer from BIM to FM&O software

Solution	Technical approaches for linking information
Using spreadsheets as simple document indexing tools	Hyperlinking
Using spreadsheets according to COBie guidelines	Hyperlinking, exchanging and synchronizing data
Using the IFC format for exchanging building information among BIM and FM&O systems	Exchanging and synchronizing data (embedding and integrating data to the recipient system)
Coupling CMMS's with BIMs via Application Programming Interfaces (APIs)	"Portal solution"
Using proprietary middleware such as EcoDomus, Onuma Systems, and FM:Interact	"Portal solution"

Table 2: A number of recent real-world applications of BIM for FM&O

Project	Approach and achievements	Issues	Source
Sydney Opera House	A unified central data repository was devised by integrating information from different resources.	There was no detailed methodology for capturing existing facilities as an accurate object-based building	(Ding et al., 2009; Moffat, 2013; Sabol, 2008; Schevers et al., 2007)
A pilot project by the US General Services Administration (GSA)	The objective was to transfer the records from the modelling tool (Revit) to the CMMS (Maximo).	Only 17 percent of the records in Maximo could be matched into Revit fields.	(Teicholz, 2013)
A federal project in New Jersey	It was planned to use COBie for transfer of data from BIM to the CMMS or CAFM systems. Onuma Systems was used for validating COBie deliverables.	The biggest problem was to identify which information was important for FM&O. Another challenge was to select a suitable CMMS in advance. The implementation of COBie has not been fully realized yet.	(Teicholz, 2013)
A federal project in Minneapolis	Their strategy was to engage the FM team in early modeling efforts.	Early identification of FM-specific systems and zones in the design model proved to be difficult, since the FM team was merely interested in as-built models and close-out documentation. The modeling team believed that there was no clear way to specify detailed data requirement in BIM compared with earlier drafting tools.	(Teicholz, 2013)
A project for integrating disparate BIM, CMMS, and BAS systems of a court-house	OmniClass Table 13 and Unifomat standards were used to specify space types as well as the facility data classification levels i.e. spaces, zones, components, and systems. CMMS's and inventory spreadsheets were the sources for collecting data for the project.	Naming conventions and data structures developed by local key personnel hindered interoperability among systems.	(Teicholz, 2013)
Mathworks project	Information synchronization through FM:Interact-Revit integration and early presence of the FM&O manager in the conceptual design phase were the main strategies. COBie was used as a reference source and as a standard rather than a transfer format. The time spent for space planning was reduced to one-tenth.	Ambiguities with specifying the level of detail (LOD) of the FM model and use of non-standard internal naming, numbering, and classification conventions for spaces and assets by the client significantly hampered the project.	(Aldaham et al., 2013)
Information administration of an existing health science center	Importing submittals of an existing health science center to TOKMO (now EcoDomus) via COBie format helped reducing the average work order duration by 8.7%. OmniClass was used for classifying the assets.	No direct integration of the CMMS data with the BIM model or linking among them was realized.	(Beatty, Eastman, & Kim, 2013)
A construction project at the University of South California	Information from BAS, CMMS (e.g. assets records), and DMS (e.g. warranty documents) were decided not to be imported to Navisworks rather be linked to within the FM system. Equipment and component schedules were composed using parametric attributes rather than hard-coded Excel entries. They had to use a wide assortment of both industry-wide and internal standards i.e. OmniClass for equipment names, and National CAD standards for equipment abbreviations, types, and instances.	Varying information requirements according to the organizational role of the FM&O actors alongside with varying naming conventions, LODs, and the varied types of data available for different assets were major challenges in the data collection phase.	(Aspurez & Lewis, 2013, p. 197)
The construction project of Xavier University in Cincinnati, Ohio	FM:Interact Space Management module was deployed for synchronizing room and element data with Revit. A person-year of data entry was avoided.	The main challenge was integrating the CAFM system (FM:Interact) with the CMMS (WebTMA).	(Afediz et al., 2013)
A residential hall at University of Wisconsin	Revit models were exported to IFC format and imported to the CMMS (TMASystems). A SQL database was then implemented for processing the information residing in the CMMS.	The equipment and room types were not defined prior to importing information to the CMMS. This slowed down the process. Another problem was that default values for the MEP equipment, e.g. airflow for the air handling units (AHUs) were inserted instead of real values. It was also difficult to specify whether the information was as-designed or as-built.	(Lewis, 2013a)
A renovation project in the University of Chicago	The participants firstly specified the types of information to be collected, how to organize the information, and how to map the information onto the CMMS (Maximo). A set of drop-down menus and pick-lists were maintained in the translational tool to handle inconsistencies among naming conventions used by design, construction, and FM&O practitioners	Since the fields mandated by COBie did not fully align with the needs of the project, COBie was replaced by a translational spreadsheet produced by a third-party database consultant.	(Lewis, 2013b)

2.2 Towards an integrated solution for a more effective FM&O practice

As evident in some of the examples introduced in previous section, the COBie initiative is helpful as a set of guidelines for identifying which data should be collected and by whom. Nonetheless, there are some downsides to implementing COBie as a standard format for conveying information to the FM&O team, e.g. mismatch of mandatory information fields in COBie with those necessitated by the business goals of each specific organization, and lack

of incentives for manufacturers to provide their product information in a COBie-compatible format.

IFC format and its associated Coordination Model View, on the other hand, have not been successful in providing consistent semantics for all stakeholders. The IFC schema is often deemed to be too rigid to be implemented during all life cycle stages of the facility (E. W. East et al., 2013; Tarandi, 2011). Another problem with IFC export as a means for information transfer to FM&O is the large file sizes and populated information that is not totally relevant or useful for FM&O (Lewis, 2013a). Such problems can be overcome in the future by development and implementation of Model View Definitions (MVDs)¹³ specific to FM&O.

Middleware solutions are relatively expensive, but are commonly used successfully by sizable organizations such as NASA and GSA. “BIM for FM Portals”, emerging some years ago (Jordani, 2010) are the most appraised FM&O information handling systems. Portals are simple and flexible from user’s perspective. They provide windows to different FM&O systems and directly interact with CMMS’s, DMS’s, and BAS’s. Technicians prefer to be able to use their own downstream systems for troubleshooting. Portals fulfill this requirement and perform queries on the model in the background (Aspurez & Lewis, 2013). Portals are flexible enough to comply with a wide variety of FM&O software, and are relatively inexpensive to develop and run (Sabol, 2013).

3 APPROACH

3.1 Theoretical framework

Among the variety of definitions of the acronym BIM (Eastman et al., 2011; GSA, 2011; Howard & Björk, 2008) and a number of proposed frameworks for research around BIM (Gu & London, 2010; Jung & Joo, 2011), the definition and research framework provided by Succar was deemed the most appropriate and clarifying one for the purpose of this study. He defines BIM as “a set of interacting policies, processes and technologies producing a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle”(Succar, 2009, p. 357). The definition is, in turn, based on an earlier definition articulated by Penttilä (2006, p. 403).

Succar regards BIM as a modern framework for organizing domain knowledge which is in turn based on the definition of “Frame” by Minsky. According to Minsky, new frameworks (in this case, Succar’s BIM framework) may be invented for new conditions or substantial changes (in this case, development of BIM technology and tools) and applied by the researcher for representing stereotyped situations (Minsky, 1974). Among the three fields of activity within BIM, our research lies in the “Technology field” and is focused on the sub-fields of software and network solutions (Succar, 2009).

3.2 Methodology

The research field of building information management in general and information management tools for FM&O in particular, is rather new and overwhelmed by empirical findings and influences of new information technologies. Hence, theory-driven and linear models have been deemed inappropriate for the purpose of this study. Instead, the principles of grounded

¹³ <http://www.buildingsmart.org/standards/mvd> (accessed 20 February 2014)

theory (Flick, 2009) have been followed and the knowledge derived from an exemplar case project has been used to complement existing literature in the field. Grounded theory is a method for qualitative studies which was introduced by Glaser & Strauss (1967) and is based on initiating the research with data collection and subsequently seeking codes, concepts, and categories that help further formulation of theories.

Firstly, the literature about some ad-hoc solutions has been consulted for presenting the status quo. Descriptions of information management configurations in eleven projects have been derived from technical reports and analyzed to extract technical issues prevailing in existing solutions.

Then, a narrative and illustrative representation and reconstruction (Flick, 2009) of a progressive IT-implementation project in the field together with its organizational context has been provided. One of the advantages of an original analysis of case studies over other methods for collecting data about information systems, e.g. interviews and surveys, is less subjectivity (Bakis, Kagioglou, & Aouad, 2006) and less distortions (Harris, 2001). The choice of the case study is a purposive sampling. This approach improves the efficiency through collecting the data that is relevant to the objectives of the research (Morse, 1998).

The observed case fulfills the requirements of a “primary selection” in that the required information is readily available to the authors. One of the authors is the designer of the system and thus has the double roles of researcher as well as the participant in the case project. This is also a retrospective study since it uses secondary data collection in an after-the-fact manner. As a criterion for studying the case project and based on the descriptions of the third dimension of the BIM framework suggested by Succar (2009), i.e. BIM Lenses, a mesoscopic lens within the FM&O domain has been applied as a mental construct for research in this field. BIM lenses are applied to Fields and Stages and are defined layers of analysis that “allow the domain researcher to selectively focus on any aspect of the AECO industry and generate knowledge views that either (a) highlight observables which meet the research criteria or (b) filter out those that do not” (Succar, 2009, p. 367). A Mesoscopic Lens implies medium coverage, focus and detail (Succar, 2009).

Finally, the most important issues from recent projects have been presented in three categories together with their respective solutions provided by the case project.

4. CASE STUDY: FM&O AT UNITEC INSTITUTE OF TECHNOLOGY (UNITEC)

In this section, the technical specifications of a BIM-driven solution developed at Unitec are studied and illustrated in their organizational context. This project has been selected for the study as it exhibits excellence in several aspects. The Unitec’s FM System integrates BIM with FM&O processes; it facilitates FM&O actors’ access to information sourced from the BIM models by sharing it with downstream applications; the implementation of the system and its applications have led to improved workflow, more effective communication of the facility information to the end users, as well as considerable costs savings in several areas.

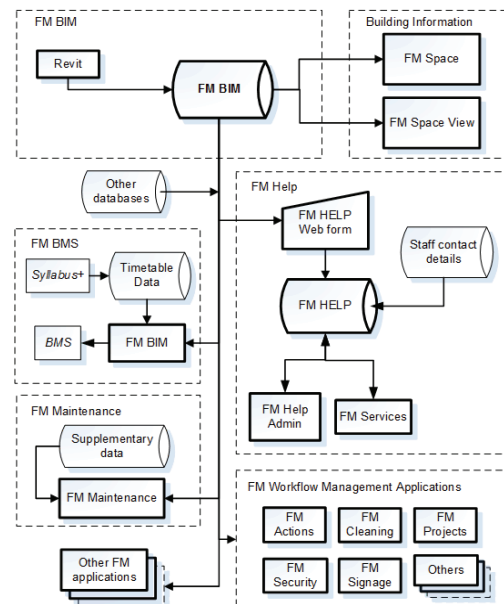
Unitec is a tertiary education facility with three campuses in Auckland, New Zealand, serving more than 23,000 students each year, and with about 800 staff members. Its Facilities Man-

agement (FM) department is located in the main campus and is managed under the directorate of Finance & Infrastructure, which is responsible for assets with a current total replacement value of approximately US\$300 million.

4.1 BIM and FM Information Integration at Unitec

The BIM project started in 2008 following a decision to undertake an in-house development of an integrated suite of FM software applications to assist with the day to day operations and to support more efficient information management. One reason behind the decision was the unavailability of a suitable off-the-shelf product for this purpose. “FM Desktop” was a promising tool, but it was discontinued soon after being acquired by Autodesk. Archibus only dealt with 2D plans and was not BIM-compatible at the time. Also, the available commercial software applications all used proprietary database systems and did not allow for user customization. Furthermore, none of them provided any BIM integration with the FM&O workflow, which was one of the main criteria behind the project. Within the project, two mainstream activities were carried out consecutively: constructing information-rich object-based models of the campus, and leveraging IT solutions for connecting those BIMs to the FM systems and databases.

Figure 1: Unitec’s FM System Overview



Using an earlier repository of CAD files called "base drawings" and complementary site surveys, a total of 191 buildings were modeled in Revit over 4 years and in three different stages, i.e. building shells; internal walls, fixtures & fittings, and roofs; space objects and other properties. The next phase is to add building services, and to incorporate underground infrastructure and above-the-ground assets such as trees, roads, and lamp posts into the campus model that is being developed.

A software tool was written using Revit’s API to automatically update or synchronize the model data at the end of each modeling session with a centralized database in a SQL Server DBMS (database management system). This is the core component of the in-house developed client/server FM Applications Suite, some of which are described in the following sections. The tool also generates Portable Document Format (PDF) floor plans, images of each space, and a normalized representation of the building geometry in Extensible Markup Language (XML) format for post-processing, e.g. energy analysis. An IFC file of each model is saved together with the Revit model in the repository and used for general post-processing and visualization.

A number of downstream applications can access the centralized database linked to the BIM models and update various information as required, which would then automatically update the models when they are subsequently opened for editing. A brief description of the Unitec’s FM System is given in Figure 1. A number of key components of the system are described below.

4.2 FM Help and Workflow Management Downstream Applications

FM Help is a help desk system developed for managing the unique work flow requirements within FM&O. The system provides a simple online form accessible on the intranet across all campuses, which is prepopulated with the essential information sourced from the BIM models, e.g. building and space numbers, departmental charge codes, and contact details of the person logging the job. Anyone on campus can log a job to request general repairs and maintenance, to notify health & safety issues, and to keep track of each job's status. Upon submission, the information is immediately available on the FM Help Admin system for moderation purposes. Once checked and verified, the job request is then assigned to the appropriate sections within FM&O and becomes available on their respective workflow management applications, e.g. FM Actions, FM Security, FM Cleaning, FM Vehicles, and FM Signage which are all web-based and accessible on desktop or portable devices anywhere on the campus.

4.3 FM Space and FM Space View for communicating building information

FM Space and FM Space View are web applications that provide access to spatial information and a set of BIM-generated floor plans in various scales. For teaching spaces such as classrooms or lecture theatres, the available equipment in each space is also listed so that the user can look up what teaching facility is available, e.g. data-show, PC, etc. At the moment, the list of equipment is derived from a database that is managed manually via an application called FM Equipment. Eventually, the equipment data will be incorporated into the BIM models, which will provide another means of updating the information automatically. Space utilization data derived from the BIM models are used for the institutional finance and accounting purposes, but also for automatically generating various regional FM statistical reports, e.g. Tribal, TEFMA, etc.

4.4 FM BMS

FM BMS application interfaces with the BMS to control the HVAC in bookable spaces. The application continuously checks the room-booking timetable database for any scheduled or one-off booking information. It sends an instruction to the BMS to turn on the ventilation or air-conditioning system half an hour before a room is scheduled to be occupied, and an instruction to turn it off 5 minutes before the end of the booking period. This has provided a huge energy saving in comparison with the previous preset daily on/off mode of operation.

4.5 FM Projects

FM Projects application provides the Projects office with an online tool to manage capital projects, e.g. new and major building works, and relocation projects. As part of the new project setup, a new record is created in the BIM models maintenance schedule, which will remain active until it is ticked off after the model is updated with the as-built information handed over to the FM office. FM Projects also provides workflow management as well as costs management functionalities. Currently, information handed over to the FM office is still in the form of printed drawings or CAD files. However, work is in progress to implement a method of assimilating as-built information directly into existing models.

4.6 FM Maintenance Costs

FM Maintenance Costs application extracts interior and exterior surface areas, and condition ratings from the BIM models, and allows managers to specify various parameters such as repair or replacement costs, and then generates maintenance cost schedules. Space condition audit is carried out visually by observation as required, but at least once every couple of

years. Space condition rating is then determined by using the weighted average of all interior surface condition ratings of that space as per NAMS (NAMS, 2006) in the scale of 1 to 5.

5 RESULTS

The Unitec's FM System is a web-based portal solution which serves all functions of CMMS's, CAFM systems, and DMS's, and at the same time integrates and seamlessly and reliably synchronizes the underlying FM&O building information databases with the BIM models. In Table 3, most significant problems in the field (derived from literature and presented in Table 2) are presented together with their respective solutions provided by the Unitec's FM System.

Table 3: Issues with current FM&O information systems versus provisions in the Unitec's FM System

Issues with current FM&O information systems	Provisions in Unitec's FM System
Issues with as-designed and as-built information	
<ul style="list-style-type: none"> Issues with identifying which data are important for FM&O 	The solution has been developed by the FM department of Unitec and thus directly addresses the requirements of their FM team on information types and LODs.
<ul style="list-style-type: none"> Issues with specifying LODs required for the FM model 	See above.
<ul style="list-style-type: none"> Varying information requirements according to the organizational role of the FM&O actors 	See above.
<ul style="list-style-type: none"> Non-useful information coming from design- and construction-intent models 	BIM models were constructed and populated in conformity with the needs of the FM&O staff.
<ul style="list-style-type: none"> The variety of industry-wide standards, local naming conventions, and data classification structures, and established colloquial names deployed in various FM&O information sources of the facility 	An in-house developed BIM Standard and Conventions handbook is used, which is based loosely on commonly used industry standards.
Issues with FM&O systems	
<ul style="list-style-type: none"> Lack of knowledge for specifying a CMMS early in the design phase 	Not applicable to this project since the system was developed for existing facilities.
<ul style="list-style-type: none"> Proprietary database systems not allowing for customization 	An industry standard, DBMS (SQL Server-ISO/IEC 9075), has been utilized to maximize data interoperability and to facilitate system maintenance. Further efforts for using IFC more centrally in the system are in progress.
<ul style="list-style-type: none"> Information fields in the CMMS's not matching those in the BIM authoring tool 	The same SQL DBMS that is derived from the BIM model also feeds information to the FM&O applications.
<ul style="list-style-type: none"> Lack of direct integration or linking among the CMMS data with the BIM model 	Unitec's FM applications suite has bidirectional links with the BIM models.
<ul style="list-style-type: none"> Lack of interoperability among the CAFM system and the CMMS 	Functionalities of both CMMS's and CAFM systems are incorporated into the web-based FM solution.
Inefficient workflow processes	
<ul style="list-style-type: none"> Manual and time-taking querying and updating routines in CAMF systems such as overlaying polygons on 2D drawings 	FM Space and FM Space View provide access to a set of BIM-generated floor plans in various scales.
<ul style="list-style-type: none"> The BIM systems and models not fully integrating with the FM&O workflow 	FM Help controls soliciting the information required for streamlining workflows from the BIM information resided in the SQL database, and channeling the query results to respective workflow applications, e.g. FM Actions, FM Security, FM Cleaning, and FM Vehicles. More specific applications such as FM Maintenance Costs and FM PropLease extract accurate and current information from BIM models for each FM&O task.
<ul style="list-style-type: none"> Issues with updating as-built models after construction 	A custom-made software synchronizes the Revit model with the SQL DBMS after each construction project. FM Projects performs the synchronization procedure.

6 PRACTICAL IMPLICATIONS

In addition to their theoretical significance, the results provide in-depth insight into prevailing issues with BIM-based IT solutions for the FM&O sector as well as examples of how those technical issues can be resolved. The results will be useful to DBMS implementers and database designers active in the FM&O sector, as well as decision-making buddies in the field.

7 CONCLUSION

According to our findings, the most important issues in implementing BIM for streamlining FM&O activities are lack of guidelines and efficient technologies for capturing BIM models of existing facilities, coping with non-consistent terminologies and taxonomies used by different actors, accurately defining and specifying requirements in BIM applications, and identifying which information and what level of detail is desired by the FM&O teams. Current open formats for transferring building information (e.g. IFC and COBie) should be enhanced and complemented or new open formats be developed for maintaining interoperability among the wide variety of proprietary tools and systems used through the entire life cycle of the building in an efficient and sustained manner.

No earlier research has so thoroughly described the overall architecture and functionalities of different components of an integrated BIM FM system based on the portal solution with regard to the status quo of the subject area in both theory and practice. Nevertheless, more research with a focus on FM&O business processes and regulatory aspects of building information hand-over are required so as to complement the findings of this paper on efficient use of BIM for FM&O.

REFERENCES

- Afedizie, E., Beatty, R., Hanselman, E., Heyward, E., Lawal, A., Nimer, E., ... Siman, D., (2013), "Case Study 4: Implementation of BIM and FM at Xavier University," , IFMA (Ed.), *BIM for Facility Managers*, Wiley, Hoboken, N.J., 233 – 249.
- Aldaham, O., Gonzalez, J., Grant, I., Harper, K., Kruger, A., Nannis, S., ... Snedeker, L., (2013), "Case Study 1: Mathworks," , IFMA (Ed.), *BIM for Facility Managers*, Wiley, Hoboken, N.J., 147–163.
- Aspurez, V., & Lewis, P., (2013), "Case Study 3: USC School of Cinematic Arts", IFMA (Ed.), *BIM for Facility Managers*, Wiley, Hoboken, N.J., 185 – 232.
- Bakis, N., Kagioglou, M., & Aouad, G., (2006), "Evaluating The Business Benefits Of Information Systems", *International Salford Centre for Research and Innovation (SCRI) Research Symposium part of the 3rd International Built and Human Environment Research Week*, in-house publishing, 280–294. Available at: http://www.irbnet.de/daten/iconda/CIB_DC10146.pdf (accessed 27 February 2014).
- Beatty, R., Eastman, C., & Kim, K., (2013), "Case Study 2: Texas A&M Health Science Center", IFMA (Ed.), *BIM for Facility Managers*, Wiley, Hoboken, N.J., 164 – 184.
- Ding, L., Drogemuller, R., Akhurst, P., Hough, R., Bull, S., & Linning, C., (2009), "Towards sustainable facilities management", P. Newton, K. Hampson, & R. Drogemuller (Eds.), *Technology, Design and Process Innovation in the Built Environment*, Taylor & Francis, Oxon, Abingdon, 373–392.

- East, B., (2013), "Chapter 5 - Using COBie", IFMA (Ed.), *BIM for Facility Managers*, Wiley, Hoboken, N.J., 107–142.
- East, E. W., & Carrasquillo-Mangual, M., (2012), *The COBie Guide: a commentary to the NBIMS-US COBie standard*.
- East, E. W., Nisbet, N., & Liebich, T., (2013), "Facility Management Handover Model View," , *Journal Of Computing In Civil Engineering*, January/February 2013, 61 – 67.
- Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (Eds.), (2011), *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, Wiley, New Jersey.
- Flick, U., (2009), *An Introduction to Qualitative Research*, SAGE Publications, Los Angeles.
- Glaser, B. G., & Strauss, A. L., (1967), *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Aldine de Gruyter, New York, NY.
- GSA, (2011), "GSA BIM Guide Series 8 for Facility Management". Available at: http://www.gsa.gov/graphics/pbs/BIM_Guide_Series_Facility_Management.pdf (accessed 23 July 2013).
- Gu, N., & London, K., (2010), "Understanding and facilitating BIM adoption in the AEC industry", *Automation in Construction*, 19(8), 988 – 999.
- Harris, H., (2001), "Content Analysis of Secondary Data: A Study of Courage in Managerial Decision Making", *Journal of Business Ethics*, 34(3-4), 191–208.
- Howard, R., & Björk, B.-C., (2008), "Building information modelling – Experts' views on standardisation and industry deployment", *Network methods in engineering*, 22(2), 271–280.
- Jordani, D. A., (2010), "BIM and FM: The Portal to Lifecycle Facility Management", *Journal of Building Information Modeling*, Spring 2010, 13–16.
- Jung, Y., & Joo, M., (2011), "Building information modelling (BIM) framework for practical implementation", *Automation in Construction*, 20(2), 126 – 133.
- Khemlani, L., (2011), "BIM for Facilities Management", *AECbytes*. Available at: <http://www.aecbytes.com/feature/2011/BIMforFM.html> (accessed 27 February 2014).
- Lewis, A., (2013a), "Case Study 5: State of Wisconsin Bureau of Facilities Management, Division of State Facilities, Department of Administration", IFMA (Ed.), *BIM for Facility Managers*, Wiley, Hoboken, N.J., 250 – 293.
- Lewis, A., (2013b), "Case Study 6: University of Chicago Administration Building Renovation", IFMA (Ed.), *BIM for Facility Managers*, Wiley, Hoboken, N.J., 294 – 313.
- Minsky, M., (1974), *A Framework for Representing Knowledge*, Cambridge, MA, USA: Massachusetts Institute of Technology.
- Moffat, B., (2013, May 14), SOH BIM FM discussion (interview).
- Morse, J. M., (1998), "Designing Funded Qualitative Research", N. Denzin & Y. S. Lincoln (Eds.), *Strategies of Qualitative Research*, SAGE, London, 56–85.
- Motawa, I., & Almarshad, A., (2013), "A knowledge-based BIM system for building maintenance", *Automation in Construction*, 29(0), 173 – 182.
- NAMS, (2006), NAMS Property Manual, New Zealand Asset Management Support (NAMS) Group.
- NIST, (2004), "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry - NIST GCR 04-867". Available at: <http://fire.nist.gov/bfrlpubs/build04/PDF/b04022.pdf> (accessed 25 July 2013).
- Owen, R., (2009), *Integrated Design & Delivery Solutions* (No. CIB Publication 328), UK: University of Salford. Available at: <https://www.cs.auckland.ac.nz/~trebor/papers/OWEN09.pdf> (accessed 27 February 2014).

- Parsanezhad, P., & Tarandi, V., (2013), "Is The Age of Facility Managers' Paper Boxes Over?", *CIB World Building Congress 2013 5-9 May 2013*, Brisbane, Australia.
- Penttilä, H., (2006), "Describing the changes in architectural information technology to understand design complexity and free-form architectural expression", *ITcon*, 11(The Effects of CAD on Building Form and Design Quality), 395–408.
- Sabol, L., (2008), *Building Information Modeling & Facility Management*, Washington, DC: Design + Construction Strategies. Available at: http://dcstrategies.net/files/2_sabol_bim_facility.pdf (accessed 27 February 2014).
- Sabol, L., (2013), "Chapter 2 - BIM Technology for FM", IFMA (Ed.), *BIM for Facility Managers*, Wiley, Hoboken, N.J., 17–45.
- Sapp, D., (2013), "Facilities Operations and Maintenance | Whole Building Design Guide". Available at: <http://www.wbdg.org/om/om.php> (accessed 30 October 2013).
- Schevers, H. A., Mitchell, J., Akhurst, P., Marchant, D. M., Bull, S., McDonald, K., ... Lining, C., (2007), "Towards digital facility modelling for Sydney Opera House using IFC and semantic web technology", *Journal of Information Technology in Construction*, 12, 347–362.
- Succar, B., (2009), "Building information modelling framework: A research and delivery foundation for industry stakeholders", *Automation in Construction*, 18(3), 357–375.
- Tarandi, V., (2011), "The BIM Collaboration Hub: a Model Server Based on IFC and PLCS For Virtual Enterprise Collaboration", *CIB W78-W102 2011: International Conference*, Sophia Antipolis, France. Available at: <http://2011-cibw078-w102.cstb.fr/papers/Paper-158.pdf> (accessed 27 February 2014).
- Teicholz, P. M., (2013), *BIM for facility managers*, (IFMA, Ed.), Wiley, Hoboken, N.J.

CHAPTER 12

INDUSTRY STUDIES

RESEARCH PAPERS IN PRACTICE TRACK 2

12.1

**Analysing Facilities Management Industry Maturity:
A Qualitative Approach**
Maulidi A. Banyani and Danny S.S. Then

12.2

Outsourcing: A Cost-saving Approach in FM?
Alexander Redlein and Michael Zobl

12.1

ANALYSING FACILITIES MANAGEMENT INDUSTRY MATURITY: A QUALITATIVE APPROACH

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ABSTRACT

Purpose: This paper presents the results of the analysis of the maturity of Facilities Management industries (FMi) in five countries namely Denmark, Hong Kong, Norway, Tanzania and the United Kingdom. The analysis is based on the '*Integrated Feeder Factors Framework (I3F)*' which is the subject of another paper.

Background: The research tested the applicability of the I3F as a tool for assessing the maturity of the FMi at a country level. This is an integrative framework which is developed in response to lack of a tool for assessing FMi maturity at country level. I3F analyses maturity by assessing the *progression* and *integration* of the key factors essential for the maturity of the FMi which are *Organisation Practice, Supply Market, Education, Professional Bodies, Research and Business Environment*.

Approach: Data were gathered from official documents, web-sites and FM experts in each of the case study countries. The interviews covered local experts within the respective countries. The collected evidences were analysed using pattern matching.

Results: FM industry in the five case study countries are found to be at various levels of maturity. UK exhibited high levels of maturity compared to the other countries. Norway, Hong Kong and Denmark were at the same level with some notable differences while Tanzania was at the lowest level.

Practical Implications: The research successful tested the I3F. This sets a foundation for assessing the maturity of FM industry at a country level. The assessment of maturity at a country level is important to FM stakeholders in charting plans for its development and longevity.

Research Limitations: The testing of the framework was conducted using qualitative approaches and a few professionals were involved from each of the five countries. However, care was taken to ensure a mix of experts from all the six areas.

Originality/Value: This is the first research which has analysed the maturity of FMi in five countries in the world using the *I3F*. The results are useful to FM stakeholders and policy makers.

Keywords: Progression, Integration, FM maturity, Integrated Feeder Factors Framework

1 INTRODUCTION

This paper presents the results of the analysis of the maturity of Facilities Management industries (FMi) in five countries namely Denmark, Hong Kong, Norway, Tanzania and the United Kingdom. The analysis is based on the '*Integrated Feeder Factors Framework (I3F)*' (The subject of another paper by the same authors – 'Theoretical Underpinnings of the Feeder Factors Integration Framework'). The research tested the applicability of the I3F as a tool for assessing maturity of the FMi at country level. I3F is an integrative framework which is developed in response to lack of a tool for assessing FMi maturity at country level. I3F analyses maturity by assessing the *progression* and *integration* of the key factors essential for the maturity of the FMi which are *FM Organisation Practice*, *FM Supply Market*, *FM Education*, *FM Professional Bodies*, *FM Research* and *FM Business Environment*. Data were gathered from official documents, web-sites and FM experts. The collected evidences were analysed using pattern matching.

2 STATE OF THE ART

This research focused on the development of an industry maturity framework for facilities management (FM). The overall objective of the project was to develop a holistic framework that will be useful in assessing the maturity of facilities management as an industry within an economy; which is lacking at the moment. Maturity models are not unfamiliar in FM; existing models such as SPICE-FM (Amaratunga et.al, 2008), Facility Management Organisation (FMO) (Turner, 2009) and the Model for Co-Maturation of FM IT & FM (Hinks, 1998) are process-based models designed to evaluate capabilities of an organizational setting. Also, country-wide maturity studies conducted in the UK (Moss, 2007), Australia (Access Economics, 2007) and in Europe (Teichman, 2009) are based on the volume of outsourcing and contribution of FM to GDP and employment opportunities. These studies have been exposed to criticisms due to their inconsistencies even when applied within the same country (Jensen, 2010).

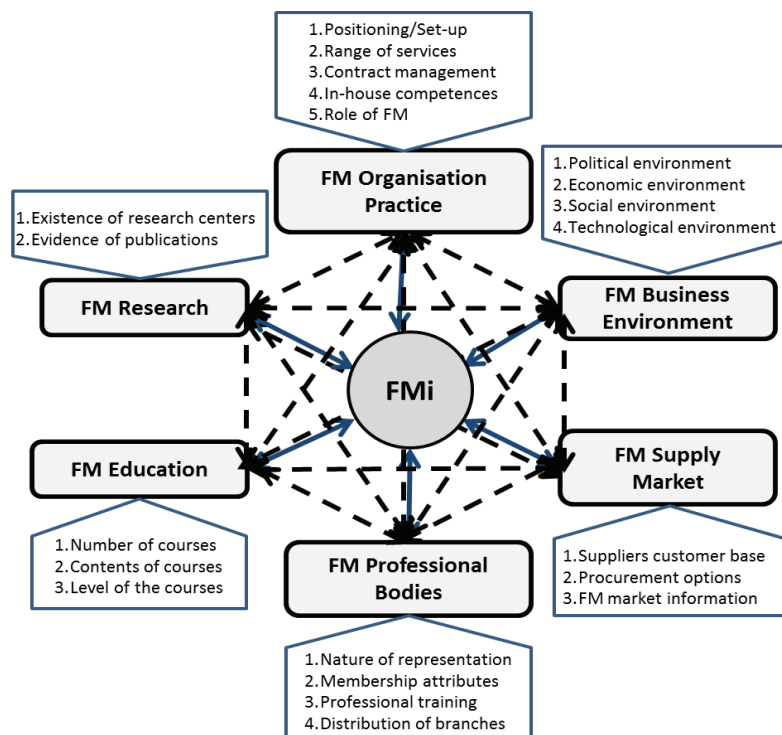
This research identified factors and criteria which were used to propose a conceptual framework for assessing the maturity of FM as an industry sector (the subject of another paper). The proposed framework which is known as '*Integrated Feeder Factors Framework (I3F)*' was intended to assess the FM maturity based on the extent of '*progression*' and '*integration*' of the six factors identified from literature review and which are referred to in this research as '*feeder factors or feeders*'. These factors are: *FM Organisation Practice*, *FM Business Environment*, *FM Supply Market*, *FM Professional Bodies*, *FM Education* and *FM Research*. The overall proposition was that, each of these factors contributes (feeds) towards the development of the FM industry within an economy and also towards the progression of the other factors. The level of contribution of each of the factors depends on its progression status and levels of integration with other feeders i.e. the higher the feeder factors progression and inte-

gration levels the higher the contribution and the overall maturity. The degree of integration between feeders is assessed based on the progression levels of four criteria, *coordination, influence, trust* and *interdependence* (CITI). In order to allow an easy assessment of the level of maturity, the framework summarised the evolutionary trends of each of the 22 progression criteria into a “*Feeder Factors Progression Matrices*” and the four integration criteria (CITI) into a “*Feeder Factors Integration Matrices*”. The dominant characteristics deduced from the two sets of matrices formed an important part of the maturity assessment. The proposed framework for assessing the level of maturity of FM at a macro-level has the following three key ingredients:

1. It provides an opportunity to understand the capabilities and performance potential of the FM industry within an economy.
2. It can be used as a self-evaluation tool for a given country over a period of time
3. It serves as a benchmark for comparing the development of FM as an industry in different countries.

The graphical representation of the framework is shown in Figure 1. In the figure, the industry is shown to exist at the middle and is surrounded by the six feeder factors which are joined to it by double arrowed lines. The bold double arrowed lines represent the interaction and the feeding process between the individual feeder factors and the industry while the dotted double arrowed lines show the relationships between individual feeder factors. Figure 1 also shows that each of the six feeder factors has a number of criteria which are used in the assessment of the dominant progression. The concepts of ‘*dominant progression*’ and ‘*dominant integration*’ are discussed further in the analysis section.

Figure 1: Integrated Feeder Factors Framework



3 APPROACH

The testing of the applicability of the I3F was conducted using five countries as case studies: Tanzania, Norway, Denmark, Hong Kong and United Kingdom. Each of these case studies countries was chosen to reflect differences in the potential level of feeder factors progression and integration. In this phase of the study, data were gathered from multiple sources using approaches such as documentary evidence, internet searches and local expert interviews. The study was guided by the philosophy that assessment of maturity is a socially constructed reality. The meaning and level of maturity can epistemologically be understood by assessing the opinions of the experts involved in the industry (within the case study countries) and also extracted from existing secondary evidence. This philosophical construct identifies itself with the post-positivist and mixed methods approaches. Therefore, major sources of data in the testing of the framework were interviews and documentary evidence. Interview proforma were prepared. The proforma comprised two sections; section 'A' dealt with the level of progression of FM factors and section 'B' inquired about the level of integration between these factors. The design of the proforma allowed the interviewee to discuss four factors out of the six. These factors were *FM Organisation Practice*, *FM Business Environment*, *FM Supply Market* and *FM Professional Bodies*. In some interviews which involved experts in academics, professional bodies and research, the other factors (i.e. *FM Education* and *FM Research*) were also included. These two factors were examined using a different approach, mainly documentary evidence and internet search.

3.1 Data Collection

Local experts in each of these countries were interviewed and requested to indicate the level of maturity of the FM industry within their countries as per the scale indicated in the proforma. The scale which was read to each of the interviewees followed the evolutionary trend of the FM industry in each of the assessed feeder factors (from Level I to Level IV). Level I was the lowest; showing the least progression while Level IV signified the highest level of progression. The proforma also prompted the interviewees to indicate the level of integration of the feeder factors within the subject country by assessing the degree of progression of each of the four integration criteria: *coordination*, *interdependence*, *trust* and *influence*, based on the same scale (Level I to Level IV).

Interviews were conducted as follows: Norway (14 interviews), Denmark (10 interviews); Tanzania (11 interviews); Hong Kong (11) and United Kingdom (7 interviews). The majority of the interviews in Norway, Denmark, and Hong Kong took place in the interviewees' offices in a face-to-face environment and lasted between 45 minutes and 2 hours. Interviews for Tanzania and the United Kingdom were conducted using telephone and Skype. The interview approach gave the researcher an advantage to effectively interact with the respondents and prompt for more information on the "whys" when an answer was deemed inadequate or unclear. This helped the research to collect more data on the reasons for the respondents choosing a specific decision on maturity level. The interviews provided raw data which were processed for fitness within a pattern matrix. It was easy to deduce a level of maturity for a specific country based on these patterns following steps which will be articulated in the analysis section.

The choice of interviewees used in this research was based on 'snowball' sampling (Corbetta, 2003). Snow-ball sampling involves identifying subjects for inclusion in the sample by referral from other subjects (Corbetta, 2003). The interviewees in Norway and Denmark were established from the list given to the interviewer by the first point of contact (also FM experts

who participated in the interview processes). In Norway, the names were gathered from various experts and in Denmark the names were obtained from only the first point of contact. For the case of Hong Kong and the United Kingdom, the list of names was obtained from one of the research supervisors. In Tanzania's case, the researcher used his acquaintances who in turn recommended more people to be interviewed. After receiving the names the interviewer sent emails to these interviewees and the communiqué mentioned the name of the person who had introduced them. This arrangement enabled access to key informants who have been able to inform the study in the development of the feeder factors and their integration levels. The strength of this technique is that it ensured that the chosen interviewees are all established experts in facilities management. This ensured validity and reliability of data collected as a true reflection of the FM industry within a country.

The research also used documentary evidence as another source of data. This involved collection of data which were collected by other researchers for other purposes (Kumar, 1999). The researcher extracted the required information from the websites of FM professional bodies, universities, research centres and FM organisations in order to gain an insight on issues related to FM industry development and maturity in the case study countries. The researcher spent some time visiting official websites of facilities management associations and education institutions in all the case study countries. The websites were helpful in understanding the formation and progress of FM industry in the respective countries. Some of the websites provided useful links to education institutions, publications, newsletter and magazine or reports. Apart from website and internet searches, the study also gathered documents from interviewees in different countries; government institutions and agents. Documentary evidence played an important role in understanding the progression of education and research in the case study countries. Documentary evidences can also be a challenge due to their lack of validity and reliability mainly due to personal bias and the use of unreliable sources. In order to deal with this situation the research used only authenticated sources i.e. data that can be verified by other researchers. The sources of the data were fully cited in the text.

3.2 Data Analysis

The data analysis was intended to achieve two objectives: (i) establish the patterns which can discriminate the levels of maturity of the case study countries and (ii) assess the compatibility of the framework in predicting the relationship between the progression and integration levels, as well as industry maturity stages. The first objective was important in assessing the maturity of individual countries. The analysis was based on pattern matching. Pattern matching involves the comparison of the empirically observed pattern(s) against a pre-defined or predicted pattern (Yin, 1984; Oliver, 2004). The matching of the two indicates the fulfillment of the predicted pattern, and hence the validity of the proposals (Stewart, 2000).

As pointed out earlier on, the key proposition of I3F is that maturity is a result of the progression and integration of the feeder factors. Levels of progression and integration of the feeder factors were established based on the *Feeder Factors Progression* and *Integration Matrices* described section 2. For this research, five (5) country cases were identified which exhibit characteristics of the various levels of the progression and integration of the feeder factors. Thus it was anticipated that the matching of the observed patterns (from the cases) to the predicted levels (summarised in the progression and integration matrices) would support the construction and application of the framework. Yin (1984) argues that comparison of the patterns needs no support from any quantitative criteria and it depends on the logical and sensible interpretation on the part of the researcher.

3.2.1 *Setting the Patterns- intra case analysis*

The analysis of data involved a five-step process:

Step 1: Transcription of Interviews: In the first step, the recorded interviews were transcribed in a verbatim manner into text.

Step 2: Observation of patterns: The second step involved the observation of the patterns on the information gathered from the interviewees as recorded in the transcriptions. This observation was intended to establish a theme from the responses (Kumar, 1999). The study was interested to discern the common characteristics of the feeder factors development and their integration as assessed by the interviewees within the case study countries. In this step the assessments of the criteria by the interviewees were extracted and presented as shown in Table 1. This table provides an extract of information from Hong Kong for criterion 'positioning' which is one the six criteria in the feeder factors 'FM Organisation Practice'. The Table was designed to show the assessed criteria in the first column and interviewees' assessment in the subsequent columns.

Each of the interviewees had a unique identification code. The code was alphanumeric - had two alphabets followed by two numbers. The alphabets used for each country were: DK (Denmark); HK (Hong Kong); NR (Norway); TZ (Tanzania) and UK (United Kingdom). Since all countries had the maximum of 11 interviewees; thus the numbers ranged from 01 to 011. The codes for respondents in Hong Kong have been shown in Table 1 for illustration purposes. The HK01 stands for the first interviewee in Hong Kong. The last column of the table was designed to accommodate the observed patterns or common characteristics of the attribute under assessment. This extraction has been performed for all criteria influencing the progression of feeder factors and integration criteria in all case study countries individually.

Step 3: Matching of Predicted to Observed Patterns: In the third step, the observed patterns were matched against the predicted patterns of the FM industry progressions discussed and summarised in the Feeder Factors Progression Matrices. The same process was also performed for the integration criteria in which observed patterns were matched to the predicted pattern summarised in the Integration Matrix. For illustration purposes the patterns for the criterion: positioning in Hong Kong is matched against the four levels of progression summarised in the progression matrices. The result of the matching is shown in Table 2.


The assessment has shown that, at the current position the cursor in Table 2, the matching between the two patterns occurs at the second level of progression of the attribute: Positioning. The matching process was repeated to all of the criteria influencing maturity of the feeder factors. The outcome of the matching process was the discrimination and recognition of various levels of progression of the criteria influencing the each feeder factors within a country.

Step 4: Assessment of Dominant Progression/Integration Level: In the fourth step, each of the level of progression assessed (from the matching of the observed and predicted patterns) in the Step 3 was recorded in a table (see Table 3) to determine a 'dominant progression level'. The same process was performed to establish dominant integration level. Dominant level is a level of progression/integration at which more criteria of various feeder factors within a country are found (based on the evolutionary Levels I-IV). Table 3 shows for Hong Kong, the industry had more criteria (14) at Level III of the progression (indicating this as the dominant level of progression), with six others at Level II and two attribute at Level IV.

Table 1: Assessment of Observed Patterns for criterion positioning in Hong Kong

Assessed Criteria	Interviewees								Observed pattern
	HK 01	HK 02	HK 03	HK 04	HK 05	HK 06	HK 07	HK 08	
Positioning	There are a few facilities managers who are sitting on boards of directors. Depending on the nature of the services some FM can provide services beyond HK. Many facilities managers are involved in technical matters and property Management and a few are on the strategic levels	There are a few people at the strategic level many are still in operational levels. But the number of people at strategic level is increasing as the importance of FM is becoming known	Many facilities managers are found in the middle to higher position. Most of the facilities managers are under COO, director of finance. I am not sure if they sit on the board	Some of the facilities managers are operational and others are strategic. Some are involved in single station and others several. There are a few facilities managers who are sitting on the board of directors	FM is getting into a strategic level than in the past. There are people in Directors and VP levels. This is the second tier management level not the first tier	In most cases are found in the middle of the senior management. Depends on the nature of the business and value of the assets	Some facilities managers are placed in the higher levels Some are technical and few are strategic	Facilities managers are placed below COO and there a few who are sitting on the board. That would have been ideal but is not happening in most of the organisation. Some are responsible for FM in other countries	Mainly facilities managers are found in the operational and tactical level (second tier management level). A few are in strategic level. There are few facilities managers sitting on the board of directors. FM department mainly provide services to one or more stations in Hong Kong. There are a few cases of facilities managers to provide services beyond HK.

Table 2: The Matching of the Criterion Positioning in Hong Kong

Criteria	Level	Predicted Pattern	Matching Level	Observed Pattern
Positioning	IV	Facilities Directors/Managers at Board Level or mainly holding strategic positions with site, national and International roles		Mainly facilities managers are found in the operational and tactical level (second tier management level). A few are in strategic level. There are few facilities managers sitting on the board of directors. FM department mainly provide services to one or more stations in Hong Kong. There are a few cases of facilities managers to provide services beyond HK.
	III	Facilities Managers mainly with tactical positions with some at strategic and operational levels reporting directly to Board Members with a regional/national and international roles		
	II	Facilities Managers mainly at Operational and tactical levels with a few at strategic positions – (site/region/national roles)		
	I	Technical/Administrative staffs (building to building/site)		

Step 5: Assessment of FM Industry Maturity: The last step is to decide on the maturity level as indicated by the results in the last table (e.g. Table 3). In deciding on the maturity level of the FM industry, the decision relies on the results of the assessed ‘dominant progression levels’ of the criteria influencing feeder factors progression and integration. Figure 2 and 3 show

that the ‘assessed dominant progression and integration levels’ are predominantly found in Level III of the *integrated feeder factors framework* within the case study country. This maturity level is known as Developmental Transition Stage (DTS).

Table 3: Assessment of the Dominant Feeder Factors Progression Level in Hong Kong

Feeder Factor	Criteria	Dominant Progress Level (Matched Pattern)			
		I	II	III	IV
1. FM Organisation Progress	1. Positioning		✓		
	2. Range of Services			✓	
	3. Mode of Services Procurement			✓	
	4. Contract Management Approaches		✓		
	5. In-house Competence			✓	
	6. Role of FM Organisation			✓	
2. FM Business Environment	7. Political Environment		✓		
	8. Economic Environment			✓	✓
	9. Social Environment				
	10. Technological Environment		✓		
3. FM Supply Market	11. Suppliers' Customers Base			✓	
	12. Procurement Options		✓		
	13. FM Market Information			✓	
4. FM Professional Bodies	14. The Nature of Representation			✓	
	15. Membership Attributes			✓	
	16. Professional Training			✓	
	17. Distribution of Branches			✓	
5. FM Education	18. Number of Courses			✓	
	19. Contents of the Courses			✓	
	20. Level of Courses				✓
6. FM Research	21. Existence of Research Centres			✓	
	22. Evidence of Publications		✓		
Frequency		0	6	14	2

Figure 2: The Feeder Factors –FMi Interfaces

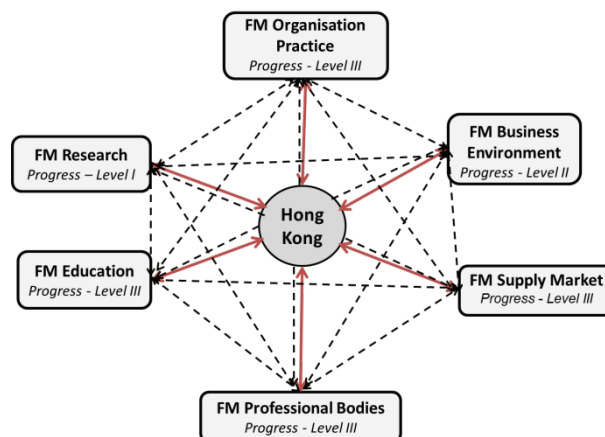
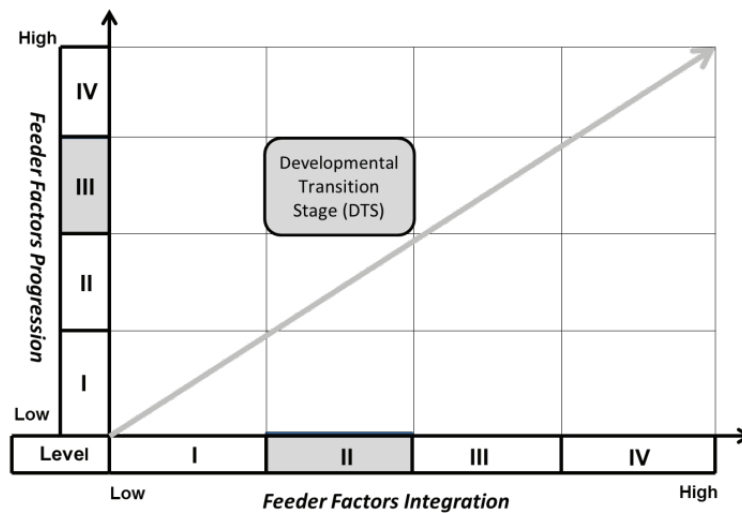


Figure 3: FM Industry Status in Hong Kong



However it must be pointed out that Hong Kong case study is unique and its characteristics are discussed in details in the results section.

4 RESULTS

In this section the research presents the results for each of the five case studies. The discussion briefly reports on the dominant progression and integration levels and the assessed maturity levels in each respective country.

4.1 Case Study 1: Denmark

4.1.1 Assessment of 'Dominant Progression and Integration Levels'

The assessment of the dominant progression and integration levels was carried out following the steps described in *Step 4* of section 3.2.1. The matching has shown that the criteria influencing each of the feeder factors development are found at the higher levels of progression (i.e. Level III and Level IV). The overall assessment reveals that for Denmark the '*dominant level of progression*' is within Level III of the *progression matrices*; 15 out of 22 criteria were identified to exist at this level. Six criteria are at Level IV of the progression while one criterion is at Level II. The assessment of '*dominant level of the integration*' reveals that three (3) criteria (*coordination, trust and influence*) are at Level III of the integration matrix while one (*Interdependence*) is at Level IV. It is therefore evident that the integration of the feeder factors in Denmark is predominantly at Level III of the *Feeder Factors Integration Matrix*.

4.1.2 Decision on the Maturity of FM industry (FMi) in Denmark

The previous section has shown that the '*dominant progression and integration levels*' in Denmark are predominantly within Level III of the feeder factors progression and integration matrices. There are also other criteria found in Level IV and Level II. This level of '*dominant progression*' of the feeder factors also reflects their contribution to the FM industry and other factors.

4.2. Case Study 2: Hong Kong

4.2.1 Assessment of 'Dominant Progression and Integration Levels'

The assessment reveals that for Hong Kong the '*dominant level of progression*' is within Level III of the *progression matrices* as 14 out of 22 criteria exist at this level. Two criteria are within Level IV while six criteria are at Level II. The assessment of '*dominant level of the integration*' has indicated that three (3) criteria (*Coordination, Interdependence and Influence*) are found at Level II of the *Integration Matrix*, while one (*Trust*) is at Level III. It is therefore evident that the integration of the feeder factors for Hong Kong is predominantly at Level II of the *Feeder Factors Integration Matrix*.

4.2.2: Decision on the Maturity of FM industry (FMi) in Hong Kong

Judging by the '*dominant progression level*' it can be decided that the feeder factors for Hong Kong are at Level III of *Progression Matrices* (Figure 2). On the other hand, the result has shown that the '*dominant integration level*' for Hong Kong is located at Level II of the *Feeder Factors Integration Matrix* (Figure 3).

The assessment of the dominant feeder factors progression and dominant integration criteria in Hong Kong do not support the existence of the positive correlations between the two. The findings have shown that, the feeder factors progressions and integration levels do not follow the normal path of maturity (see Figure 3). The ideal proposed development of the FM industry was supposed to follow a diagonal path shown by the arrowed line in Figure 3. Nevertheless, this is not the case. The feeder factors have shown higher levels of *progression* (Level III) and the integration is in the lower levels (Level II). This situation coincides with one of the four conditions used in the assessment of maturity levels which states that: '*higher levels of progression may occur in lower levels of integration*'. In such a situation it is recommended that separate counts on the frequency of the individual feeder factors, '*progression and integration levels*' be performed to determine the dominant level. The result of the counts has shown the dominance of Level III. Due to this rule; it can be argued that for Hong Kong, the FM industry is located at Level III of the Integrated Feeder Factors Framework (I3F) which is known as *Developmental Transition Stage (DTS)*.

Since Hong Kong is a unique case, the study reviewed the interviews for a second time to search for reasons on the variations of the progress of the feeder factors and their integration. One of the possible drivers for variation is the influence of the foreign feeder factors in the development of the industry. The study has identified for example that, out of the six FM courses in Hong; three are offered by universities in the United Kingdom jointly with the local institutions. The courses in FM offered at HKU-SPACE (jointly with the University of Greenwich) are accredited to the Royal Institutions of Chartered Surveyors (RICS-UK) and Hong Kong Institute of Construction Managers (HKICM). The Bachelor Degree in FM at the Hong Kong College of Technology is conferred by the University of Central Lancashire and is accredited by the Chartered Institute of Buildings, UK (CIOB). Similarly, it is noted that the FM industry in Hong Kong is dominated by international suppliers/services providers such as ISS, JLL and CBRE. These suppliers or services providers also operate in other Asian countries while using Hong Kong as their regional office. Apart from FM service suppliers, Hong Kong is also a home of many multi-national organisations (foreign) which operate in a number of countries in Asia. This has given an opportunity for *FM Organisation Practice* to be higher in terms of roles, competences, range of services and mode of procurement. While these factors have a higher contribution (Level III) towards the development of the industry their connection to the local environment and other FM players is limited (Level II).

4.3 Case Study 3: Norway

4.3.1 Assessment of 'Dominant Progression and Integration Levels'

The assessment reveals that for Norway the '*dominant level of progression*' is at Level III of the *Feeder Factors Progression Matrices* as 14 out of 22 criteria are found at this level. Five criteria are at Level IV and three criteria are at Level II. The assessment of '*dominant level of the integration*' has indicated that three (3) criteria (*Coordination, Trust and Influence*) are found at Level III of the *Feeder Factors Integration Matrix* while one (*Interdependence*) is at Level IV. It is therefore evident that the integration of the feeder factors for Norway is at Level III of the *Feeder Factors Integration Matrix*.

4.3.2: Decision on the Maturity of FM industry (FMi) in Norway

The '*dominant progression and integration levels*' for Norway are predominantly within Level III of the feeder factors progression and integration matrices. There are also other criteria found at Level IV and Level II. The result shows that feeder factors *FM Research and FM Business Environment* contribute to the development and maturity of the FM industry in Norway at Level IV while others are contributing at Level III. The assessment of '*dominant progression and integration levels*' of the feeder factors in Norway support the existence of positive correlations between the two. The feeder factors progressions and integration levels have been shown to tally at Level III of the *progression matrices*. Thus, it can be concluded that for Norway the FM industry is found at Level III of the *Integrated Feeder Factors Framework (I3F)* which is known as *Developmental Transition Stage (DTS)*.

4.4 Case Study 4: Tanzania

4.4.1 Assessment of 'Dominant Progression and Integration Levels'

The assessment reveals that for Tanzania the '*dominant level of progression*' is at Level I of the *Feeder Factors Progression Matrices* as 14 out of 22 criteria are found at this level. It has been shown that five criteria are at Level II and three at level III. The assessment of '*dominant level of the integration*' indicates that all four (4) criteria (*Coordination, Interdependence, Trust and Influence*) are at Level I of the *Feeder Factors Integration Matrix*.

4.4.2: Decision on the Maturity of FM industry (FMi) in Tanzania

The '*dominant progression and integration levels*' for Tanzania are predominantly within Level I of the feeder factors progression and integration matrices. There are also other criteria found in Level II and Level III. The result shows that feeder factors *FM Education* contributes to the development and maturity of FM industry in Tanzania at Level II while others are contributing at Level I. The assessment of '*dominant progression and integration levels*' of the feeder factors in Tanzania support the existence of positive correlations between the two. The feeder factors progressions and integration levels have been shown to tally at Level I of the *progression and integration matrices*. It can be concluded that in Tanzania the industry is in Level I of the *Integrated Feeder Factors Framework (I3F)* which is known as *Initial Formative Stage (IFS)*.

4.5 Case Study 5: The United Kingdom

4.5.1 Assessment of 'Dominant Progression and Integration Levels'

The assessment reveals that for United Kingdom the '*dominant level of progression*' is at Level IV of the *Feeder Factors Progression Matrices* as 20 out of 22 criteria are found at this level. The remaining 2 are in Level III of the *Feeder Factors Progression Matrices*. The assessment of '*dominant level of the integration*' indicates that all four (4) criteria (*Coordination, Interdependence, Trust and Influence*) are found at Level IV of the *Feeder Factors Integration Matrix*. It is therefore evident that the integration of the feeder factors for United Kingdom is predominantly at Level IV of the *Feeder Factors Integration Matrix*.

4.5.2: Decision on the Maturity of FM industry (FMi) in the United Kingdom

The assessment of the 'dominant progression level' and 'dominant integration levels' of the feeder factors in the United Kingdom support the existence of the positive correlations between the two. The feeder factors progressions and integration levels have been shown to tally at Level IV of the *Feeder Factors Progression Matrices*. It can be concluded that in United Kingdom the industry is found at Level IV of the *Integrated Feeder Factors Framework* (I3F) which is known as Full Mature Stage (FMS).

5 PRACTICAL IMPLICATIONS

The *Integrated Feeder Factors Framework* (I3F) is designed to assess the maturity of facilities management as an industry sector. Its formulation and scope of application is different from the maturity models developed earlier for FM. The earlier models on FM maturity (Amaratunga et.al., 2008; Hinks, 1998 and Tuner, 2009) were focused on assessing maturity of FM processes within an organisational context. I3F is an adaptation of two maturity models; the Industry Life Cycle Maturity Models (ILCM) and Capability Maturity Models (CMM). I3F borrowed the structure of the CMM and the scope of ILCM. This research provides I3F as a comprehensive tool which can be used to assess and understand the maturity stages of the FM industry. The six feeder factors of I3F are essential for the development of many industries regardless of the state of the economy. The framework can help the stakeholders to understand the level of maturity and areas which require bolstering for achieving the optimal state of readiness and capabilities. It can also be used to lobby for recognition and assistance from other stakeholders within a country.

6 CONCLUSION

The research has shown that the five countries are within various stages of maturity and capabilities. Denmark, Hong Kong and Norway are found within Level III of FM industry Maturity as assessed by I3F. In Norway and Denmark, the feeder factors progression and integration dominantly exhibited characteristics found at the Developmental Transition Stage of I3F. Thus, the stakeholders are required to make more efforts in improving these factors to attain the fourth level. In Hong Kong the situation was different; the research has shown that the feeder factors have higher progression than integration. This is mainly due to the influence of foreign feeder factors into that market. Thus, efforts are required to not only tout for the progression of the feeder factors but also the need to integrate the foreign feeder factors into the local systems. The results for Tanzania have shown that feeder factors are predominantly at Level I of the progression and integration. This signifies that FM industry in Tanzania is at its Initial Formative Stage (IFS). Efforts are required from the stakeholders to put in place measures which can help to improve the industry status. In the United Kingdom, the industry is shown to exist at the highest level of maturity i.e. Full Mature Stage (FMS). The industry is known to all stakeholders and it is insitutionalised. Thus, efforts are required to uphold and maintain this status quo. This is a first study which has used the I3F in analysing the maturity of FM industry. The study has been able to identify the level of maturity and areas where the industry are not performing well or are lagging behind in terms of progression and integration in each of the five countries. The research can be used by stakeholders in devising programs and plans for improving or maintaining the progression and integration of the feeder factors and the status of the industry as a whole.

This research was limited to the development of an industry maturity framework for FM as

an industry sector within an economy. This was done by assessing six factors which influence maturity of an industry. These factors involve processes from various independent organisations and actors. It was not easy to assess their impact from a single organisation's point of view. The study was carried out on a country basis. This would mean that, geographically, the testing was conducted within a country as a unit of assessment. The use of a country (wider geographical area) would suggest the use of methods which can encourage participation of more experts (in terms of numbers). However, the study intended to gather in-depth information from competent local experts (quality of information). Using competent local experts' interviews, the study was able to gather enough information to assess the maturity of the FM industry within the respective case study countries. There is no reason to assume that the assessment conducted in each country by local experts does not reflect the situation in a country. The study has proposed that in future a survey may be conducted to further test reliability of this result.

REFERENCES

- Amaratunga, D., R. Haigh, R., Baldry, D., & Sarshar, M. (2008). Process improvement in Facilities: The SPICE Approach. In K. Alexander, *Facilities Management Processes* (pp. 90-106). Naarden, The Netherlands: European Facility Management Network
- Access Economics. (2007). *Facility Management Industry: Statistical Profile for 2005-06*. Australia: Access Economics Pty Limited.
- Banyani, A. M. & Then, D.S.S. (2014) Theoretical Underpinnings of the Feeder Factors Integration Framework.
- Corbetta, P. (2003). *Social Research: Theory, Methods and Techniques*. London: Sage Publications.
- Hinks, J. (1998). A Conceptual Model for the Interrelationship between Information Technology and Facilities management process capability. *Facility*, 16(9/10), 233-245.
- Jensen, P. (2010). *The FM Sector and its Status in the Nordic Countries*. Copenhagen: DTU Management Engineering.
- Kumar, R. (1999). *Research Methodology: A Step by Step Guide for Beginners*. London: Sage Publications
- Moss, Z. (2007, December). How Big is FM? *FM Market Intelligence*, pp. 37-39.
- Oliver, P. (2004). *Writing Your Thesis*. London: Sage Publications.
- Stewart, P. (2000, July 28). Strategic IT Maturity of Construction Companies. *PhD Thesis*. Melbourne, Australia: Department of Construction, Royal Melbourne University Institute of Technology
- Teichmann, S. (2009, September). FM Market Size in Europe. *European FM Insight*(11).
- Turner, J. (2009). *Notes from the Field*. Retrieved October 20, 2009, from IWMSNews.com/FM: <http://www.IWMSNews.com/FM>
- Yin, R. (1984). *Case Study Research-Design and Methods*. London: Sage.

12.2

OUTSOURCING: A COST-SAVING APPROACH IN FM?

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ABSTRACT

Purpose – The purpose of this paper is to measure use and practices of outsourcing to understand the functions, reasoning, advantages, disadvantages and trends involved in the outsourcing decision and process.

Background (State of the Art) – The theoretical background underlines the assumption that organizations who outsource their facility services, gain more added value than organizations that control their facility services in-house.

Approach (Theory/Methodology) – The research is based on the Mixed Method Approach and the Mixed Model Research. A large sample of companies is interviewed and the data (answers) statistical analyzed. The population for the surveys were the Top 500 companies in Austria. Interviewees were the Facility Managers themselves or the persons responsible for all FM tasks.

Findings/Results – The results show that the most outsourced services are cleaning, winter service and heating/ventilation/air condition. Most of the companies had between 3 to 10 external service providers under contract. Companies have to find a trade-off between the costs for complex administration and coordination according to a high number of external service providers and the dependence on the external service provider.

Practical implications – Although organizations may outsource for cost related reasons, there are no guarantees that expected savings will be realized. The results of the statistical analyses show that it is important to specify which and how many facility services have to be outsourced.

Research limitations – The effects of Outsourcing on an organization's cost are not yet fully understood and the variables and their relationships are more complex than expected. More detailed analysis of different industries or countries are possible to gather more information about Outsourcing and an expansion of the data within this research field.

Originality/value – The sample represents a solid statistical base for analyses and permits to make statements which are statistically well-founded.

Keywords: Outsourcing, Facility Management, Cost Savings, Facility Services

1 INTRODUCTION

Facility Management (FM) is a key function in managing facility services and working environment to support the core business of the organisation (Chotipanich, 2004). Outsourcing is a common practice for companies and an important element in business strategy. Outsourcing mostly refers to the development of a new contractual relationship where tasks formerly carried out by in-house employees are transferred to one or more companies. This practice of replacing in-house support functions with support bought from external service providers has expanded during the 1990s (Bröchner et al., 2002). In the area of FM the facility services/activities are contracted out to external service providers (organizations that are responsible for the delivery of one or more facility services) instead of carried out in-house. Depending on the size of the company or institution, some or many facility services are outsourced. Making the decision about what should be provided in-house or outsourced is not always easy to determine. There are pros and cons for both (Campbell, 2011). Outsourcing decisions are typically based on the potential to realize cost savings through economies of scale and specialization by the outsourcing providers. One link between added value and outsourcing is found in cost reduction objectives, ranging from redirecting capital, refocusing on corporate core business, transferring real estate related risks and increasing occupational flexibility (Jensen et al., 2012). Although there are significant risks (e.g. poor performance/quality, less flexibility) that may be realized if outsourcing is not successful. The pros and cons of outsourcing have become a frequent topic in the literature (Kremic et al., 2006).

Since 2005 the Vienna University of Technology (TU Vienna) analyze the demand side of FM on a yearly basis in different European countries such as Austria, Germany, Bulgaria, Romania, Turkey and the Netherlands. The researches have been based on (standardized) questionnaire survey. The research objectives were to help facility professionals better understand the functions, reasoning, advantages and disadvantages and trends typically involved in the outsourcing process and to better understand how the outsourcing process is managed. In detail, following research questions should be answered: Is there a value through outsourcing and how are trends (according to different studies/articles) in outsourcing implemented in companies? Is there a trade-off between the outsourcing degree respectively the number of external service providers and cost savings? Does an increasing number of external service providers respectively an increasing outsourcing degree automatically lead to more cost savings?

2 STATE OF THE ART

The fundamental argument for introducing outsourcing and market competition to management services is that such delivery approach can save costs by reducing bureaucratic inefficiencies, allowing large organizations and governments to access economies of scale, by-passing costly labour and generating competition among service providers (Lam, 2011). The International Facility Management Association (IFMA) has conducted a tracking survey on the practice of outsourcing in the facility management field. In 1993 and 1999, IFMA conducted surveys of its members on outsourcing issues. Again in 2006, IFMA conducted another study of its members to measure use and practices of outsourcing. In 2006 a total of 487 complete surveys were collected from IFMA members, for a final response rate of 10 percent.

The report reveals that over the past years, the use of out-tasking (hiring individual, specialized vendors to provide one or more FM functions) has decreased from 91% in 1993 to 77% in 2006. The steepest decline has come from 1999 to 2006 with a corresponding increase in the number of companies that are outsourcing (hiring full-service, single vendor to provide many services bundled together). The mainly outsourced/out-tasked are housekeeping, architectural design, trash and waste removal and landscape maintenance. The most important criteria when deciding whether or not to outsource are financial in nature: controlling costs, freeing capital funds, improving ROI, and reducing turnover and training costs. Over one-half of companies have saved money through outsourcing/out-tasking and one-third has seen a quality improvement. Two out of five companies have brought services back in-house after outsourcing the service. Typically reasons are to regain control of the service, either in terms of costs, quality or response time. Part of an outsourced/out-tasked function is kept in-house. In recent years, the standard length of outsourcing contracts has stayed the same at most companies. One-fourth of Facility Managers use longer-term contracts and 15% use shorter contracts. One-half of the companies have consolidated their vendor base to use fewer service providers (IFMA, 2006). In the year 2000 a survey of Swedish and UK process industry companies was performed. Ten managers were interviewed, based on a questionnaire. The survey confirms that the willingness among process industry companies to transfer support services to external contractors depends on cost advantages while restrained by the risk of disruption of core production processes (Bröchner et al., 2002). DeAnne (2008) points out, based on the literature findings, that competitive tendering can yield 10 to 30% of cost savings with no adverse effect and sometimes an improvement in service quality (Lam, 2011).

Several studies on the risk factors associated with outsourcing of functions have been reported. Kremic et al. (2006) developed a survey of risk factors for outsourcing IT functions. These risk factors include: unrealised savings with a potential for increased costs; employee morale problems; over-dependence on a supplier; loss of corporate knowledge and future opportunities and inadequate requirement definitions. Atkins and Brooks (2009) developed a set of risks that organisations face in their pursuit for more and effective facilities management. These risks have the potential to hinder or even negate attempts at achieving value for money. They include e.g. inadequately resourced or inexperienced client function; poor relationship between contractor and contract manager; possible loss of control over the facilities management function; inadequate definition of the scope and content of services; financial failure of chosen service provider during contract period; lack of education and training in facilities management and excessive monitoring of contract performance. Ikediashi et al. (2012) analysed the risks associated with outsourcing of FM services in Nigeria. They developed a list of critical risks using descriptive statistics and used Principal Component Analysis (PCA) to select the most representative of the risks in each risk category. They field survey involved 37 client based respondents and 24 vendor based respondents cutting across the top, middle and low managerial levels in their companies. Findings from the study reveal that poor quality of services was rated the most critical while security issues was rated second. This was followed by inexperience of client. Findings from PCA indicate that three risk factors namely inexperienced client, interruption to supply of services and unclear responsibilities and targets showed significant loadings to represent the client risk. Financial failure of chosen vendor, poor quality of services and vendor underperformance showed significant loadings to represent vendor risk. Also contract risk is represented by four factors namely absence of benchmark for quality, inadequate definition of scope and services, lack of standard forms of contract for facility services, inadequate planning of policies implementation and loss of strategic flexibility. Poor relationship between clients and vendors and conflict of

interest exhibited significant loadings to represent relationship risk. Security requirement issues and fear of uncertainty represent the general risks. Outsourcing, even popular and driven by global competition, is still risk prone (Ikediashi et al., 2012).

The theoretical background underlines the assumption that organizations who outsource their facility services, gain more added value than organizations that control their facility services in-house. That is why in this research organizations are asked how they control their facility services and which percentage they source out.

3 APPROACH

There are currently three major research paradigms: quantitative research, qualitative research and mixed research. The major characteristics of quantitative research are a focus on deduction, confirmation, theory/hypothesis testing, explanation, prediction, standardized data collection and statistical analysis. The characteristics of qualitative research are induction, discovery, exploration, theory/hypothesis generation, the researcher as the primary “instrument” of data collection and qualitative analysis (Johnson and Onwuegbuzie, 2004). Quantitative and qualitative methods have particular lacks of strengths (Johnson and Christensen, 2007). So the authors used the research method “Mixed Research”. It is a type of research in which qualitative and quantitative methods, techniques or other paradigm characteristics are mixed in one overall study (Johnson et al., 2007). Its logic inquiry includes the use of induction (discovery of patterns), deduction (testing of theories and hypotheses) and abduction (uncovering and relying on the best of a set of explanations for understanding one’s results). The goal is to draw from the strengths and minimize the weaknesses of both research methods (quantitative and qualitative) in single research studies and across studies. Taking a mixed position allows researchers to mix and match design components that offer the best chance of answering their specific (research) questions (Johnson and Onwuegbuzie, 2004).

Based on the Mixed Method Research, the studies include quantitative and qualitative research phases. The first step was to analyse and validate the existing data and results of the former surveys. In addition, qualitative studies (literature review, brainstorming, expert interviews and group discussions) were used to analyse problems, define additional parameters and improve the questionnaire. With the help of the parameters new hypotheses were set up. Based on the hypotheses, a new questionnaire was set up and the survey was carried out. An extended ex post office analysis of the existing profit and loss reports and balance sheets was performed. The main goal of this step was to provide more accurate data. An indexation of the respective years should verify that the results are comparable (Redlein and Sustr, 2008). The whole survey process from creating the questionnaire to evaluating results is under yearly review. Questions are rephrased if necessary, added or deleted. It is important that the questions are short and clear otherwise the risks of misunderstanding and wrong answers are very high (Hizgilov and Redlein, 2011). Also the mixed model research was used. The qualitative and quantitative approaches are mixed within a research phase (Johnson and Christensen, 2007). The questionnaire included summated rating scales (quantitative data collection) and open-ended questions (qualitative data collection). The questionnaire was subdivided into the main areas: Companies in general and FM organisation (for example questions about the industry of the company, number of employees, turnover, number of sites), value added (e.g. cost drivers and savings through the introduction of FM, increase of productivity through the use of FM), the way of service provision (e.g. number of external service providers, outsourced facility services/areas), IT support (e.g. used IT system, areas of IT support) and Sus-

tainability (CSR etc.). Depending on the answers there are up to about forty questions. The population for the survey were the Top 500 companies published by an Austrian business magazine called "Trend" (ranking is sales driven). Interviewees were the Facility Managers themselves or the persons responsible for all FM tasks according to the European Norm EN 15221-1. Tools for the survey were phone, personal face-to-face interviews and/or E-Mail. From the listed Austria's Top 500 companies, in the year 2012 82 companies participated in the survey and in the year 2011 70 companies participated in the survey. The phone interviews were carried out by one researcher, thus the manner of questioning was always the same. This was done to secure data quality. To ensure the plausibility and validity of the data the results of the different research steps were compared with each other and with other studies in this research field. The data (answers) were entered in a MS Access database and afterwards exported into statistical programmes (SPSS, MS Excel), analyzed and evaluated. As mentioned before the questionnaire included also questions with open answering possibilities. That means that answers need to be reviewed, if necessary renamed and afterwards clustered to make the findings comparable. The renaming and clustering was double checked to ensure correctness. At least the results are validated by questioning the outliers, retracements and changes in trends. Additional points were validated through internet research.

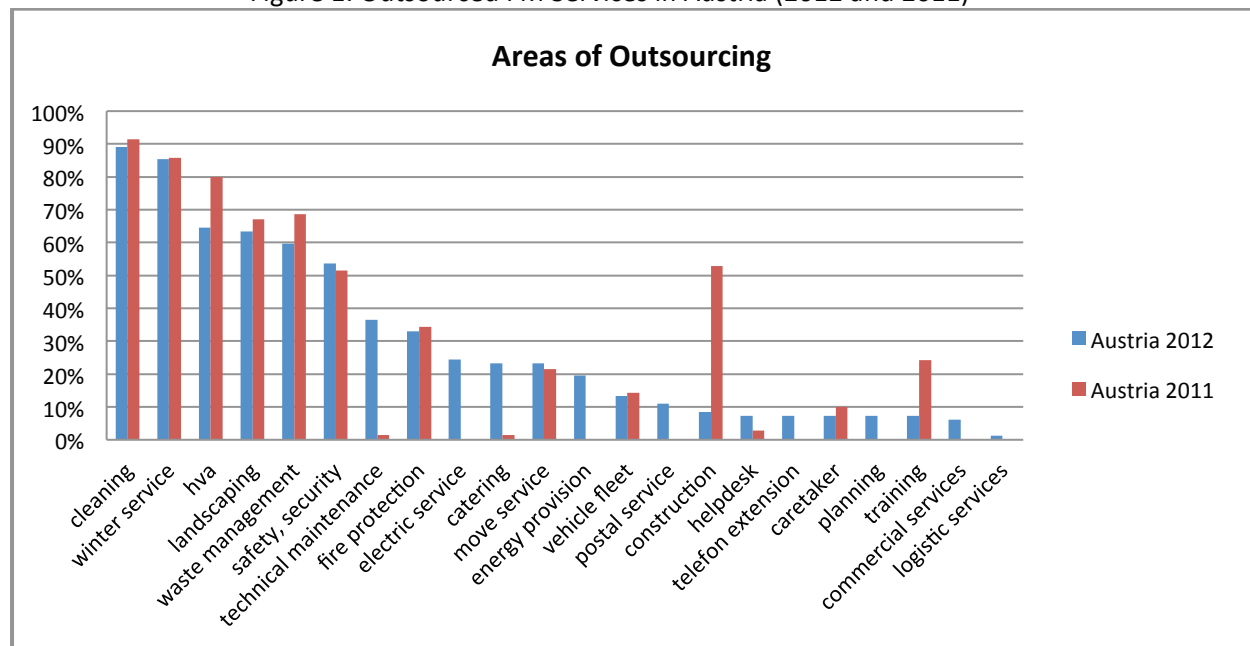
The authors already started to define statistical models to prove if there is an (significant) correlation between different variables/parameters. Regression analyses were used to make quantitative estimates of economic relationships between different variables/parameters to specify that a dependent variable is a function of one or more independent variables (Studenmund, 2006). Regression analysis is a technique to study and measure the relation between two or more variables. The goal is to estimate the value of one variable as a function of one or more other variables. The estimated variable is called the dependent variable and is commonly denoted by Y. The variables that explain the variation in Y are called independent variables. They are normally denoted by X. When Y depends on only one X it is called simple regression analysis, but when Y depends on more than one independent variable it is called multiple regression analysis. If the relation between the dependent and the independent variables is linear, it is a linear regression analysis. Regression analysis seeks as well to establish the reliability of estimates and consequently the reliability of the obtained predictions. Regression analysis allows furthermore examining whether the results are statistically significant and if the relation between the variables is real or only apparent (Dodge, 2008). This paper presents some first results of the quantitative part of the surveys in Austria for the years 2012, 2011 and 2010 especially Outsourcing and Cost Savings/Value Added.

4 RESULTS

In 2012 most of the surveyed companies (63%) had between 3 to 10 external service providers and only 31% more than 10 service providers under contract. While in the year 2011 the share of companies commissioning more than 10 service providers was 26% and 68% had between 3 and 10 external service providers. In the year 2010 the share of companies commissioning between 3 to 10 external service providers was 41% and 47% had more than 10 external service providers under contract. Over the last years most of the surveyed companies had between 3 to 10 external service providers. This reduction since the year 2010 in the number of commissioned service providers shows the tendency to engage external service providers with integrative service offer. The less external service providers a company has to commission, the less complex is the internal administration and coordination of contracts in connection with external service providers. On the other side the share of companies with

only 1 to 2 external service providers under contract remains on a low level. In 2010 the share of companies with only 1 to 2 external service providers under contract was 12%. This share of companies under contract decreased in 2011 and 2012 to 6%. Although (according to different studies and articles) the less external service provider a company has to commission, the less complex is the administration and coordination of contracts, there is no trend towards only one external service provider with integrative service offer. One problem is that, if important functions are being outsourced, an organization is mightily dependent on the external service provider. Risks such as bankruptcy and financial loss cannot be controlled. Outsourced facility services/areas are illustrated in Figure 1.

Figure 1: Outsourced FM Services in Austria (2012 and 2011)



The first three positions are cleaning (2012: 89%, 2011: 91%), winter service (2012: 85%, 2011: 86%) and heating/ventilation/air conditioning (2012: 65%, 2011: 80%). Whereas some years ago the main purpose of FM was cost savings, nowadays purposes and demands of FM have changed. Aspects like the improvement of the market position became more and more important. Moreover, qualitative aspects like higher satisfaction of the employees which result in higher motivation and productivity are also consequences of the introduction of FM. It is still not possible to quantify all benefit effects. While the cost savings and the productivity improvement can be calculated, the strategic competitive advantage is only decidable (Hauk, 2007). In our studies value added of FM includes cost savings and increase in productivity on the one side and on the other side cost drivers. Cost drivers require differentiated cost planning and cost control. They are measures of cost causation and resource use and output (Leidig, 2004). In the questionnaire/survey productivity was defined as: Increase in productivity = More output with the same input e.g. staff; respectively increase of output per unit of input. The biggest cost driver in 2012 was energy, which was mentioned by 27% of the answering Facility Managers. This cost driver was followed by more "labour-intensive" areas such as safety (13%), maintenance/repair (12%) and cleaning (12%). The most relevant areas of cost savings in 2012 (number of mentions/frequencies to total respondents in %) were energy (51%), cleaning (44%) and personnel (21%). The area administration (18%) was the most

named area in which an increase in productivity could be observed (answers in % to total respondents). This area was followed by maintenance/repair (17%) and personnel (16%).

The theoretical background underlines the assumption that organizations who outsource their Facility Management respectively their Facility Services, gain more added value than organizations that provide their Facility Services in-house. That is why in the research organizations are asked how they control their Facility Management functions and which percentage they source out (Smit, 2008). To see if the degree in outsourcing of Facility Services has an effect on the added value of an organization, the degree in outsourcing is compared with the parameter annual savings. The Regression analysis was used to make quantitative estimates of the relationship between these two variables/parameters. The dependent variable are the annual savings (in %). The independent variable is the degree of outsourcing. The results are presented in Table 1.

Table 1: Regression Analysis (degree of outsourcing – annual savings)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,095 ^a	,009	-,022	8,196

a. Predictors: (Constant), degree of outsourcing

ANOVA^a

Model	Sum of Squares	df	Mean Square	F	Sig. F
1 Regression	19,471	1	19,471	,290	,594 ^b
Residual	2149,588	32	67,175		
Total	2169,059	33			

a. Dependent Variable: annual savings (%)

b. Predictors: (Constant), degree of outsourcing

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig. t
	B	Std. Error	Beta		
1 (Constant)	9,702	3,274		2,963	,006
degree of outsourcing	,026	,048	,095	,538	,594

a. Dependent Variable: annual savings (%)

The R square value identifies the proportion of variance in annual savings accounted for by the degree of outsourcing. In this case .9% of the variance in annual savings is explained by the outsourcing degree. R square is an accurate value for the sample drawn but is considered an optimistic estimate for the population value. The Adjusted R Square is considered a better population estimate. It corrects the bias and therefore has a lower value. The effect size as estimated by Adjusted R square is .022 (2.2%). This is basically a medium effect (effect size < 1-10% = medium effect). The standard error of the estimate is the standard deviation of the expected values for the dependent variable annual savings. The table/regression ANOVA

tests for a linear relationship between the variables. The F statistics is the ratio of the mean square for regression to the residual mean square. The F and associated p-values (Sig. F, Sig. t) reflect the strength of the overall relationship between the independent variable (degree of outsourcing) and the dependent variable annual savings (F, Sig. F) and between each individual independent variable and annual savings (t, Sig. t). The value of F in the ANOVA Table is not significant (Sig. = .594). It is above the .05 level. A statistical test is said to show significance if the p-value is less than the significance level ($p < .05$). The Table Coefficients presents the kernel of the regression analysis, the regression equation. The values of the regression coefficient and constant are given in column B of the table. The t statistics tests the regression coefficient for significance and Sig. t is the p-value of t. Here .594 means $> .05$, i.e. t is not significant beyond the .05 level for the variable degree of outsourcing (Kinnear and Gray, 2008; George and Mallery, 2008).

Table 2: Means (degree of outsourcing – annual savings)

Annual Savings (%)						
Degree of outsourcing (classified)	Mean	N	Std. Deviation	Median	Minimum	Maximum
0-4%	-	0	-	-	-	-
5-24%	10,00	5	7,211	10,00	0	20
25-49%	12,40	5	7,162	10,00	5	20
50-74%	8,33	9	5,852	10,00	1	20
75-100%	13,13	15	9,775	13,00	0	30
Total	11,29	34	8,107	10,00	0	30

If the degree of outsourcing influences the degree in added value (in this case: the degree in perceived annual savings), the degree in added value should be higher when the degree of outsourcing increases. The results in Table 1 and Table 2 can confirm this only partially. Table 2 shows that an increasing outsourcing degree leads to a slight increase in annual savings. But as can be seen in Table 1 there is no statistical significant correlation between the degree of outsourcing and the annual savings, i.e. the degree of outsourcing has only a weak effect on the annual cost savings. Only .9% of the variance in annual savings is explained by the outsourcing degree. It can be concluded, that there is no significant relation between the degree of outsourcing of an organization and the way respondents perceive the added value of their Facility Management organization.

As mentioned before many facility services such as cleaning, safety, winter service and catering are outsourced (see Figure 1). So outsourcing is still an important strategy for companies. Over the last years most of the surveyed companies had between 3 to 10 external service providers who perform these facility services. Table 3 illustrates the number of external service providers under contract and the annual savings. Also the Regression analysis was used. The dependent variable are the annual savings (in %). The independent variable is the number of external service providers.

Table 3: Regression Analysis (number of external service providers – annual savings)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,191 ^a	,036	,011	8,047

a. Predictors: (Constant), number of external service providers

ANOVA^a

Model	Sum of Squares	df	Mean Square	F	Sig. F
1 Regression	93,161	1	93,161	1,439	,238 ^b
Residual	2460,614	38	64,753		
Total	2553,775	39			

a. Dependent Variable: annual savings (%)

b. Predictors: (Constant), number of external service providers

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig. t
	B	Std. Error	Beta		
1 (Constant)	10,326	1,339		7,714	,000
Number of external service providers	,016	,013	,191	1,199	,238

a. Dependent Variable: annual savings (%)

R square has a value of 3.6%. Only 3.6% of the variance in annual savings is explained by the number of external service providers. The value of F is not significant (Sig. = .238). It is above the .05 level. The p-value of t (Sig. t) has a value of .238, i.e. t is not significant beyond the .05 level for the variable number of external service providers. There is no statistical significant correlation between the number of external service providers and the annual savings, i.e. the number of external service providers only has a weak effect on the annual cost savings. The results of the year 2011 are similar to the year 2012. R square has a value of .7%. The value of F is not significant (Sig. = .726). The p-value of t (Sig. t) has a value of .726, i.e. t is not significant beyond the .05 level for the variable number of external service providers.

Table 4 shows that the mean and median of the annual savings for companies with 3 to 10 external service providers are highest and decrease with an increasing number of external service providers. An increasing or high number of external service providers do not automatically generate more cost savings (annual savings).

Table 4: Means (number of external service providers – annual savings)

Number of external service providers (classified)	Annual Savings (%)					
	Mean	N	Std. Deviation	Median	Minimum	Maximum
1-2	10,00	2	,000	10,00	10	10
3-10	11,16	25	7,739	10,00	0	30
>10	10,31	13	9,612	8,00	0	30
Total	10,83	40	8,092	10,00	0	30

The less external service providers a company has to commission, the less complex is the internal administration and coordination of contracts in connection with external service providers. Indirect costs may include contract monitoring and oversight, contract generation and procurement, intangibles and transition costs. These costs may increase with an increasing number of external service providers and reduce the annual savings. Another view is that external service providers with integrative service offer cannot provide the full-range of services required of companies that outsource. They offer a range of disparate services and fail to do anything well (Drion et al., 2012). If important functions are being outsourced, an organization is mightily dependent on the external service provider. Risks such as bankruptcy and financial loss cannot be controlled. These risks increase with a decreasing number of external service providers. This may also reduce the annual savings of the demanders. Companies have to find a trade-off between the costs for complex administration and coordination of contracts according to a high number of external service providers and the dependence on the external service provider.

5 PRACTICAL IMPLICATIONS

Outsourcing is an important strategic solution to the provision of a range of facility services (Usher, 2004). Organizations may expect to achieve many different benefits through successful outsourcing, although there are significant risks that may be realised if outsourcing is not successful. Much of the literature identifies the desire to save costs as an explanation why outsourcing occurs. Although organizations may outsource for cost related reasons, there are no guarantees that expected savings will be realized. A high or increasingly number of external service providers does not automatically lead to more cost savings. There is increasing evidence that cost savings have been overestimated and costs are sometimes higher after outsourcing. There are also some additional indirect and social costs (e.g. low morale, lower productivity) that may be incurred. Indirect costs may include contract monitoring and oversight, contract generation and procurement, intangibles and transition costs. These costs increase with an increasing number of external service providers and therefore reduce the (annual) savings. Literature also indicates that in industries with complex technologies and systems, internal synergies may be lost when some functions are outsourced. This could result in less productivity or efficiency among the remaining functions. There are also potential pitfalls when outsourcing for strategic reasons. Organisations may “give away their crown jewels” if they outsource the wrong functions (Kremic et al., 2006). Therefore, outsourcing outcomes are not automatically assured, unless the risks are either properly identified and assessed before commencement of outsourcing transaction or effectively managed during the execution stage (Ikediashi et al., 2012). Each decision regarding to Outsourcing must be care-

fully reviewed from a risk and benefit perspective (Downey, 1995). Facility Managers have to decide which and how many facility services are carried out to external service providers. It is important to specify which work has to be outsourced and to communicate expectations of how it will be provided (Kleeman, 1994). Service level agreements (SLA) and/or key performance indicators (KPI) can be used to ensure performance and conditions of service delivery and also measure the performance of facility services.

6 CONCLUSION

Even though FM does not equal outsourcing, it is still an important method within FM. The most outsourced facility services are cleaning, winter service, heating/ventilation/air condition and outdoor area. Most of the companies had between 3 to 10 external service providers. The mean and median of the annual savings for companies with 3 to 10 external service providers are highest. But between the number of external service providers and the degree of outsourcing and the annual savings is only a weak correlation. Although organizations may outsource for cost related reasons, there are no guarantees that expected savings will be realized. The literature also warns that there is an initial tendency to overstate benefits through outsourcing and that suppliers are likely to perform better in the beginning of a contract to make good first impressions. If outsourcing is to be fully integrated as a valid and respectable management tool, it must be pursued with a clear sense of where, when and why it leads to enhanced value respectively cost savings (Alexander and Young, 1996). The effects of outsourcing on an organisation's cost are not yet fully understood and perhaps the variables and their relationships are more complex than expected. More detailed analyses of different industries and/or countries are possible to gather more information and an expansion of the data within this research field.

REFERENCES

- Alexander, M., Young, D. (1996), "Outsourcing: Where's the value?", *Long Range Planning*, Vol. 29, No. 5, pp. 728-730.
- Bröchner, J., Adolfsson P., Johansson, M. (2002), "Outsourcing facilities management in the process industry: A comparison of Swedish and UK patterns", *Journal of Facilities Management*, Vol. 1, No. 3, pp. 265-271.
- Campbell, J. L. (2011), *Facility and Property Management Guidebook*, Campbell Consulting Group, Utah, 2nd edition.
- Chotipanich, S. (2004), "Positioning facility management", *Facilities*, Vol. 22, No. 13/14, pp. 364-372.
- Dodge, Y. (2008), *The Concise Encyclopedia of Statistics*, Springer Verlag, Berlin, Heidelberg.
- Downey, J. M. (1995), "Risks of outsourcing - Applying risk management techniques to staffing methods", *Facilities*, Vol. 13, No. 9/10, pp. 38-44.
- Drion, B., Melissen, F., Wood, R. (2012), "Facilities management: lost, or regained?", *Facilities*, Vol. 30, No. 5/6, pp. 254-261.
- George, D., Mallery, P. (2008), *SPSS for Windows Step by Step: A simple guide and reference*, Pearson Education, Boston, 8th edition.
- Hauk, S. (2007), *Wirtschaftlichkeit von Facility Management*, Dissertation, TU Wien.

- Hizgilov, T., Redlein, A. (2011), "Einsparungspotenziale, Produktivitätssteigerungen und Kostentreiber im Facility Management", *Journal für Facility Management*, Vol. 3, pp. 18-25.
- IFMA (2006), "An inside look at FM Outsourcing", summary available at: <http://www.ifma.org/publications/books-reports/an-inside-look-at-fm-outsourcing> (accessed 12 January 2014).
- Ikediashi, D. I., Ogunlana, O., Boateng, P., Okwuashi, O. (2012), "Analysis of risk associated with facilities management outsourcing: A multivariate approach", *Journal of Facilities Management*, Vol. 10, No. 4, pp. 301-316.
- Jensen, P. A., van der Voordt, T., Coenen, C. (2012), *The added value of facilities management: concepts, findings and perspectives*, Polyteknisk Forlag, Lyngby.
- Johnson, R. B., Christensen, L. (2007), *Educational Research: Quantitative, Qualitative and Mixed Approaches*, SAGE Publications, Thousand Oaks, 3rd edition.
- Johnson, R. B., Onwuegbuzie, A. J. (2004), "Mixed Method Research: A research paradigm whose time has come", *Educational Researcher*, Vol. 33, No. 7, pp. 14-26.
- Johnson, R. B., Onwuegbuzie, A. J., Turner, L. A. (2007), "Toward a Definition of Mixed Methods Research", *Journal of Mixed Methods Research*, Vol. 1, No. 2, pp. 112-133.
- Kinnear, P., Gray C. (2008), *SPSS 15 made simple*, Psychology Press, New York.
- Kleeman, W. B. (1994), "Out-tasking: More Widespread than Outsourcing in the USA", *Facilities*, Vol. 12, No. 2, pp. 24-26.
- Kremic, T., Tukul, O. I., Rom, W. O. (2006), "Outsourcing decision support: A survey of benefits, risks and decision factors", *Supply Chain Management: An International Journal*, Vol. 11, No. 6, pp. 467-482.
- Lam, T. Y. M. (2011), "Outsourcing of housing services in Hong Kong: optimization of transaction value", *Journal of Facilities Management*, Vol. 9, No. 2, pp. 114-126.
- Leidig, G. (2004), „Prozesskosten-Management. Arbeitskreis Klein- und Mittelbetriebe (AKM) Eschborn“, available at: http://www.rkw-kompetenzzentrum.de/fileadmin/media/Dokumente/Publikationen/2004_FB_Prozesskosten-Management.pdf (accessed 29 October 2013).
- Redlein, A., Sustr, F. (2008), "Economic Effective Implementation of FM", Research Paper, TU Wien.
- Smit, I. (2008), "A study on the added value of Facility Management", Thesis Report, Wageningen UR.
- Studenmund, A. H. (2006), *Using Econometrics: A practical guide*, Pearson Education, Boston, 5th edition.
- Usher, N. (2004), "Outsource or in-house facilities management: The pros and cons", *Journal of Facilities Management*, Vol. 2, No. 4, pp. 351-359.

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The CIB Facilities Management conference is arranged biannually by CIB Working Commission W070. The conference in 2014 was organised in collaboration with W111 Usability and W118 Clients and Users and the local host Centre for Facilities Management at the Technical University of Denmark.

This joint conference amongst working commissions focuses on the importance of increased openness in the world and how FM can create value for all stakeholders. With the first announcement we invited for inputs on the more specific conference themes. Based on those inputs a number of themes were defined for the call for paper. Abstracts and papers have been through a rigorous double blind review process resulting in the acceptance of 38 papers included in this publication. The papers cover the following themes:

- Building condition and evaluation
- Case studies
- Clients and users
- Energy management
- FM innovation and technology
- FM performance and industry maturity
- Industry studies
- Sustainable building development
- Sustainability and climate change
- Usability and learning environments
- Usability and user experiences
- Workplace management

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ISBN 9788750210696

